EVOKED POTENTIAL CORRELATES DURING THE PROCESSING OF COMPLEX PICTORIAL STIMULI

By

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EVOKED POTENTIAL CORRELATES DURING THE PROCESSING OF COMPLEX PICTORIAL STIMULI

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Major Department: Clinical Psychology

An understanding of the processing of pictorial stimuli into long-term memory would be a potentially useful addition to our current understanding of why pictures are better remembered than their verbal counterparts. Recent studies using event related potentials (stimulus locked computer averaged EEG's recorded at the scalp, ERPs) indicate that ERPs may reflect changes in brain state which accompany the processing and evaluation of incoming information.

The purpose of the present study was to 1) review the major theoretical views of why pictures are better remembered than words; 2) discuss the findings from studies which have investigated complex pictorial stimuli such as faces and scenes; 3) review related findings from the evoked potential literature (particularly findings on evoked responses in relation to information processes, such as memory and the orienting response); and finally, 4) develop a methodological approach using the cortical evoked response to investigate the processing of complex pictorial stimuli.

Seventeen right-handed male college students with uncorrected vision were shown 2 classes of stimuli (familiar and unfamiliar). Four hundred color landscape slides were presented across 5 sessions of 80 slides with a stimulus duration of 400 milliseconds and an interstimulus interval of 3 to 4 seconds. Subjects were instructed to memorize each slide; no other response was required. After a 2-week interval the experimental procedure was repeated for each of the 17 subjects.

The EEG was monopolarly recorded from scalp positions C3, C4 and PZ, reference to linked mastoids. A diagonal EOG channel was also collected for the detection and subsequent exclusion of eye movement artifacts from the collected data. The data were digitized at 125 samples/second/channel (8 msec sampling interval on 1,000 Hz sampling frequency over the 4 channels).

It was hypothesized that the P300, P400 and slow wave evoked potential components to the familiar class of stimuli would display decreased microvolt amplitude with increased familiarity. The results obtained from a repeated measures analysis of variance for the P300 and P400 components were consistent with the initial hypotheses (*p* § 0.05). Significant findings were not obtained for the slow wave component (*p* ¶ 0.05).

These findings and their limitations are discussed in terms of habituation and their implications for further research.

CHAPTER I
INTRODUCTION

1.1 Memory for Pictures and Words

Our ability to retain pictorial stimuli such as faces and scenes, better than their verbal labels, has been demonstrated across a number of studies. The purposes of the present dissertation were to 1) review the major theoretical views of why pictures are better remembered than words; 2) discuss the findings from studies which have investigated complex pictorial stimuli, such as faces and scenes; 3) review related findings from the evoked potential literature, particularly findings on evoked responses in relation to information processes, such as memory and the orienting response, and finally, 4) develop a methodological approach using the cortical evoked response to investigate the processing of complex pictorial stimuli.

Pictures are better retained than their verbal labels in many paradigms (Paivio, 1976), and much recent work has attempted to find out why. The dominant theoretical notion in the area has been Paivio's dual-coding theory, which ascribes the superior retention of pictures to their greater likelihood of inducing both an imaginal code and a verbal code (Craik, 1979) (see Appendix 1).

Alternatives to the dual-coding account of picture superiority are the unitary code theories (see Appendix 1). They suggest that pictures induce a richer, more detailed representation in memory, and this in turn makes them more distinctive at the time of retrieval (Nelson, 1978; Potter, Valian, Faulconer, 1977). Whether the richer encoding induced by pictures is specifically visual in character, or whether both words and pictures are encoded in a common abstract propositional form is still a moot point. It is clear, however, that verbal and pictorial information can influence each other (Pezdek, 1977; see Appendix 1 and below; Sperber et al., 1979; and in Chapter I, 1.2, see Loftus, Miller, Burns, 1978).

Paivio's theory is one which involves different types and levels of representation, and it would seem relatively easy to modify his view from the notion that "the critical factor is the number of codes activated by the orienting task" (D'Agostino, O'Neill, Paivio, 1977, p. 253), to the idea that performance depends on the distinctiveness of the multilevel representation (Craik, 1979). This latter view is advocated by Nelson (1978) in the context of his sensory-semantic model. He reviews evidence which demonstrates that words are retained better than pictures if the words are phonemically distinctive and the pictures are visually confusable. Thus, this indicates that it is the level of depth of representation within a code (i.e., verbal/imaginal, fellowing Paivio, 1976) that is important and not simply the number of codes activated. Nelson (1978) further reported that pictures do not automatically induce encoding of their labels, suggesting that pictures and words may not be processed by different memory systems.

Still, other lines of research tend to support the argument that words and pictorial stimuli are represented in different memory systems. Studies in which pictures and words have been used as primes to facilitate the naming of picture and word targets have produced results that are difficult to explain without proposing separate encoding mechanisms for the two types of stimuli (Sperber, McCauley, Ragain, and Weil, 1979). In this study the effects of semantic priming on picture and word processing were assessed under conditions in which subjects were required simply to identify stimuli (label pictures or read words) as rapidly as possible. Stimuli were presented in pairs (a prime followed by a target), with half of the pairs containing members of the same semantic category and half containing members of the same semantic category and half containing unrelated concepts. Semantic relatedness was found to facilitate the identification of both pictures and words, and obtained interactions of semantic relatedness and stimulus quality suggested that semantic priming affects the initial encoding of both types of stimuli. In one experiment subjects received pairs of pictures, pairs of words, and mixed pairs composed of a picture and a word or of a word and a picture. Significant priming effects were obtained on mixed as well as unmixed pairs, supporting the assumption that pictures and words access semantic information from a common semantic store. Of primary interest was the significantly greater priming obtained in the picture-picture pairs than in word-word or mixed pairs. This suggests separate memory processes for verbal and pictorial information. Furthermore, the occurrence of prosopagnosia, a brain lesion-induced inability to remember familiar faces, once was interpreted by some to support a dissociation between the processing of faces and other pictorial stimuli (see Appendix 2).

In examining whether words and pictures are represented in separate memory systems Deffenbacher et al., (1981) proposed that if separate mechanisms with different operating characteristics existed for words, pictures, and faces, then one might observe differences among the stimuli in major parameters of memory performance such as retroactive interference or long-term forgetting. Direct comparisons of recognition memory for concrete nouns, pictures of common objects, pictures of landscapes, and pictures of faces showed that memory for nouns and objects was relatively immune to retroactive interference (i.e., learn list a, then learn list b, and tested on list a type of paradigm) in a test given shortly after study; increased slightly in susceptibility as time passed since seeing the targets and the interfering items; and suffered considerable forgetting over a long retention interval. Memory for landscapes was highly susceptible to interference at the short retention interval, did not increase in susceptibility to interference with time, and also suffered substantial long-term forgetting. Like that for landscapes, memory for faces was greatly hurt by interferences shortly after study. However, unlike any of the other stimuli, faces resulted in decreased susceptibility to interference at the longer retention interval and generally resulted in little long-term forgetting. The authors interpreted these results as being generally consistent with the dual-coding hypothesis, in that both landscapes and faces do contrast with nouns in susceptibility to interference, indicating the possibility of different mechanisms with different operating characteristics for pictures and words. In summarizing their data on retroactive interference and long-term retention they concluded from their studies that different classes of stimuli are handled differently in memory. However, they were unable to determine whether the difference is a structural one wherein different kinds of stimuli are processed by different mechanisms; or a functional one in which all mechanisms produce codes for all stimuli, with some codes being more useful and others less so in a subsequent memory task. Given the results obtained by Deffenbacher et al. (1981), a measure of stimulus learning, as well as a measure for the retrieval of stimuli already learned, would be of interest in accounting for these differential findings. It may be that with complex pictorial stimuli and words the inconclusive results obtained from examining processes and products from tasks which require the retrieval of information from long-germ memory are confounded by differential learning processes for different classes of stimuli.

1.2 Complex Pictorial Stimuli and Long-Term Memory

In response to the trend of studying materials which occur in our normal everyday life, a number of experiments have reported on memory for complex pictorial stimuli, such as faces and scenes. Patterson and Baddeley (1977), in examining long-term memory (LTM) for faces, have shown that initial judgments of personality (i.e., rating the depicted person on scales of nice-nasty, intelligent-dull) were associated with higher levels of subsequent recognition than were judgments of physical characteristics (e.g., small-large nose). While the difference in recognition was small, it was quite reliable, suggesting that personality ratings may be effective in directing the subjects' attention to the face as a whole.

Some of the growing experimental work on LTM memory for scenes also has implications for giving testimony in court. Loftus, Miller, and Burns (1978) showed subjects a series of slides of an automobile accident; between presentation of the slides and a recognition test for a critical slide, the subjects were exposed to verbal information that was either misleading, consistent with, or irrelevant to the scenes viewed. The authors found that the misleading information was incorporated into the memory for the events and gave rise to later recognition errors; further, the misleading information had greater impact if presented just before the retention test than just after initial viewing of the slides. As with Pezdek's work (1977), this result demonstrates the integration of verbal and pictorial information in memory.

In general, our ability to recognize previously viewed real-world pictures has led to three basic findings (Franken, Rowland, 1979). First, we are able to recognize accurately a picture as having been previously viewed, even when the set from which the picture belonged was extremely large. Standing, Conezio, and Haber (1970) and Standing (1973), using 2,500 and 10,000 pictures respectively, have obtained recognition accuracy scores of 90% or better. Second, there appears to be little loss over time. Nickerson (1968) and Standing (1973) have reported good performance after several days, while Bahrick, Bahrick, and Wittlinger (1975) have reported that the ability to recognize portraits of classmates taken from a school yearbook was remarkably good even after 50 years. Third, it appears humans require very little time to process pictorial information. Rosenblood and Pultron (1975) found very little loss in accuracy when viewing time was reduced to 80 milli-seconds (msec). Potter (1976) has concluded that the average picture required only 1000 msec exposure. Franken and Rowland (1974) found performance was very good even when exposure time during recognition was as short as 20 msec. What these findings seem to indicate is that memory for pictorial stimuli, such as faces and scenes, is remarkably large, efficient and stable. As previously indicated, a fundamental question which has yet to be fully examined in the literature is whether the greater recall of pictorial stimuli is the result of differential learning processes, differential retrieval processes, or both. Studies so far have taken for granted the processes for acquiring information into long-term memory, and have focused almost entirely upon measuring the processes and products for the retrieval of information for long-term memory.

It can be reasoned that if memory for pictures and words is represented in separate memory systems, one might observe not only differences of memory performance (as did Deffenbacher et al., 1981), but too, one might expect differences in processes involved with the consolidation of pictorial stimuli into long-term memory (i.e., learning). And as previously discussed, information concerning the processing of pictorial stimuli may provide researchers with additional, and potentially useful information. This information may prove particularly useful in examining whether memory processes for faces are distinct from the processes for other types of pictorial stimuli (see Appendix 2), such as landscape scenes (Deffenbacher et al., 1981).

Recent developments in recording stimulus evoked responses (ERPs) from the scalp may provide the needed specificity in examining the processing of pictorial stimuli. The evoked response is defined as the average of the stimulus locked electroencephalographic (EEG) responses, see Chapter VI. A number of studies employing event related potentials have shown that the latency and amplitude of certain components are not only related to the physical parameters of stimuli (exogenous components), but certain components (endogenous components) may also reflect higher cortical processes such as memory.

CHAPTER II

EVENT RELATED POTENTIALS

2.1 Event Related Potentials and Information Processing

One of the factors that has attracted many behavioral scientists to event related potential (ERPs, or evoked potentials) has been the opportunity they present for the study of selection and processing of information by the human brain. Initially, studies of human information processing were confined to examining stimulus input in relation to output, as measured by some form of performance measure, and inferring intervening cortical processes. Event related potentials offer a chance to obtain additional data on these processes, and consequently it has become important to establish their relationships both to the stimuli which evoke them, and where appropriate, to the resulting performance (McCallum, 1978).

Early work with ERPs concentrated on the processes involved in the registration of stimuli and on activity primarily during the first 100 or 100 milli-seconds (msec) after their receipt. As such, it was primarily concerned with the physical parameters of the stimulus and their reflection in the sensory system. However, as signal analysis techniques developed, it became apparent that evoked components could extend up to 400 msec or more following the stimulus, and that even later and slower potential changes could extend over several seconds in conditions involving association between stimuli. These later and extended components appeared to reflect the psychological demands and overall contextual significance of the stimuli rather than their simple physical properties. By virtue of this characteristic they have frequently been designated endogenous, to distinguish them from the earlier, exogenous, components. One of the problems which has faced behavioral scientists involved in the study of human information processing has been the fact that by no means do all incoming stimuli result in changes which manifest themselves in immediate overt behavior, although they may well cause changes which have an effect on subsequent behavior. The endogenous components of ERPs constitute a possible means of distinguishing these different kinds of changes (McCallum, 1978).

2.2 Endogenous and Exogenous Evoked Potential Components

When a stimulus is repeatedly delivered, a sequence of ERP components can be observed to begin shortly after stimulus onset and last for about a quarter of a second. These components are essentially constant in amplitude, latency, and scalp distribution for a given stimulus. They have the status of components because their amplitude and latency are affected by the physical parameters of the stimuli as well as by the general state of the subject

(Donchin, Ritter, McCallum, 1978). In particular, their scalp distribution varies as a function of stimulus modality. These components may be considered exogenous (for a more comprehensive review, see Callaway et al., 1978). That is, they are evoked by events extrinsic to the nervous system. They occur whether the subject attends to the stimuli or not, is awake or asleep, aroused or relaxed. The absence of, or distortion in, any of these components suggests a neurological deficit and provides a basis for clinical assessment.

By contrast, endogenous components may be elicited in the absence of external stimulation. Their characteristics may be related only partially to the physical parameters of the evoking stimulus. A variety of experimental paradigms have shown that these components are associated with such matters as the subject's prior experience, his intentions, his decisions, and may also be modulated by task parameters and experimental instructions.

While several criteria can be used to identify endogenous and exogenous components, the distinction is heuristic. Like many other distinctions, it is easy to identify extreme examples of each category; however, there is always a range over which one class shades into the other. A useful distinction, which can serve as a guide for experimenters, is that whenever variance in the ERP cannot be attributed to variance in the physical stimulus or noise, the ERP components can be considered endogenous. Whenever the variance is attributable to the physical nature of the stimulus, the components are exogenous (Donchin et al., 1978).

2.3 A Catalog of Endogenous Components

Attention will be drawn to only those endogenous components whose existence has been well established (Donchin et al., 1978). All the components reviewed have been recorded, repeatedly, in several laboratories, using more than one experimental paradigm. The following components meet these criteria.

2.3.1 N200

This component is elicited whenever a rare or unexpected event occurs. It is of particular interest because it can be elicited by stimuli that are in the periphery of the subject's attention. Unlike the other endogenous components it appears sensitive to the modality of the stimulus. The positive-going return of this component is sometimes labeled P3a.

N200 is best seen when a train of stimuli is delivered at a constant rate and from time to time when the omission occurs yields N200 followed by P300 (Klinke, Fruhstorfer, and Finkenzeller, 1968). The reason N200 is most clearly delineated in these circumstances is that the exogenous P200 component, which can overlap in latency, and thereby partially or totally obscure N200 when they occur together, is not elicited by the absence of stimulation. A critical feature of this experimental design is the rate at which the stimuli are delivered can facilitate the development of internal rhythms in subjects so that they can anticipate the points in time when stimuli should occur. Picton, Hillyard, and Galambos (1974), for example, found that progressive increases in the interstimulus interval of the train of stimuli produced smaller amplitude and longer latency N200 components to the omitted stimuli. This finding is presumably due to the greater variability of N200 latency and the poorer time-locking of the N200 component to stimulus omissions.

2.3.2 P300

This robust endogenous component is reliably recorded in association with task relevant, rare stimuli. However, the label is loosely applied in that this component's latency may range from 275-600 msec (Donchin et al., 1978). It is characterized by its scalp distribution as it tends to be larger in the central and parietal electrodes. It is further characterized by a very specific response to experimental manipulations.

The P300 component of the human ERP is one of the more robust endogenous components, and in a sense, the best understood. The basic phenomenon has been well described by Sutton et al. (1965). A positive-going peak, with a latency of about 300 msec, can be modulated in amplitude by variations inthe psychological context in which the stimuli are presented. In particular, identical physical stimuli will, or will not elicit a P300 as a function of the degree to which their appearance does, or does not, surprise the subject. The evidence is also rather strong that the stimulus that elicits the P300 must somehow engage in the subject's processing resources. By and large this has meant that the stimulus must in some way be task relevant. There is some evidence to suggest that P300 amplitude is sensitive to trial-to-trial variations in the subjective probability that the subject ascribes to each event. The latency of P300, which is often considerably longer than 300 msec (P300 with latencies of 500-600 msec have been reported), has been shown to depend on the time subjects require to recognize a stimulus for what it is. Given these data it is possible to propose that P300 can serve as an important adjunct to studies of human information processing. For a current review of the P300, see Pritchard (1981).

2.3.3 Slow Wave

This is a slow potential shift that, as far as is known, is affected by the same variables that affect P300, except that it has a different scalp distribution. Whereas P300 appears largely as a positive-going potential peaking on the parietal scalp, the slow wave is positive-going at the parietal electrodes and negative-going in frontal electrodes. As the slow wave is so closely associated with P300, more on these two components will be discussed later.

2.3.4 The Contingent Negative Variation (CNV)

This term is normally used to describe the slow negative shift of potential that occurs during the warned foreperiod preceding a motor or mental task. It begins approximately 400 msec after the warning stimulus and, normally, terminates after the imperative stimulus; that is, the stimulus demanding a response or decision by the subject.

Hillyard (1973) has classified paradigms in which CNVs are generated into four general types: 1) holding a motor response in readiness; 2) preparing for a perceptual judgment; 3) anticipation of a reinforcer, positive or negative; and 4) preparing for a cognitive decision. In a more general sense an individual's behavior is directed toward a planned action in response to a sequence of two or more events. The action referred to can be an overt motor response, the inhibition of a motor response, or a decision. Another component, the readiness potential, is also a slow negative shift in cortical potential preceding a planned action, but in this case the action is self-initiated and is not governed by immediate external signal.

The scalp distribution of the CNV is widespread. It is largest over the vertex, where, in a standard warned reaction time (RT) paradigm, amplitudes in the range of 14-20 microvolts are characteristic for the normal population. These diminish only slightly at the lateral-central locations, C3 and C4, but show a marked reduction over temporal regions. Amplitudes also show a progressive diminution anteriorly and posteriorly from central regions. Small CNVs are to be found over occipital areas. CNVs over frontal areas are about half the size of CNVs recorded at central electrodes. They progressively diminish in amplitude as the electrode is moved in a prefrontal direction. At the nasion they are virtually absent (Donchin et al., 1978).

Early interpretations of the CNV saw it as dependent upon the association formed between the warning and imperative stimuli. The nature of the association has been the subject of some controversy, although there has been little dispute about the experimental evidence. Numerous experimental paradigms have been employed to manipulate a wide range of psychological and other variables. Significant correlations were reported between CNV amplitude and attention, arousal motivation, anticipated energy output, conation, orientation, expectancy, preparation for action, and other variables. At first sight this diversity might seem to confuse attempts to arrive at a satisfactory account of the behavioral concomitants of the CNV, but closer inspection reveals that most of the constructs are among the more loosely defined in psychology, and there is substantial overlap in their usage. Collectively they delineate a recognizable but ill-defined area of human cognitive function (Donchin et al., 1978). Part of the difficulty stems from the fact that this is the region of private access, where quantification begins to lose the foothold of objective measurement.

CNVs appear to reflect an activity that is focal for the individual in processing information form the environment. Many investigations have invoked selective attention as the psychological correlate of the CNV. In the first report of CNV (Walter, Cooper, Aldridge, McCallum, and Winter, 1964), one of the correlates was described as attentiveness. This relationship was further elaborated by Hillyard and Galambos (1967), McCallum (1969a), Tecce and Scheff (1969a, 1969b), and Tecce and Scheff (1970), and has been reviewed by Hillyard (1973). Yet, it is not clear whether the use of this concept has led to a deeper understanding of the functional significance of the CNV. As Donchin (1973) has pointed out, one gains very little understanding by assigning to a poorly understood phenomenon an equally poorly defined concept as a label.

2.3.5 The Readiness Potential (RP)

Like the CNV, the RP is a negative shift which precedes an action. It is distinct in the sense that it appears prior to self-paced voluntary responses. It occurrence is independent of the presence of an eliciting, or command, stimulus.

Reviews of the data available on the RP have been made by Deecke, Becker, Grozinger, Scheid, and Kornhuber (1983), McAdam (1973), and Kutas and Donchin (1977). The term RP is normally used to refer to that slow negative shift of potential that precedes a self-initiated action. Generally, the action involves a motor movement, but there is evidence that a similar shift precedes the making of a decision that does not result in an immediate motor action. The rise time of the RP varies considerably and may be as much as 1 to 3 seconds. It is characteristically observed over a period of several hundred msec preceding the action. It terminates, at least over precentral areas, in a further negative component having a sharp rise time. This latter component has been variously referred to as N2, motor potential, and motor cortex potential and has been the subject of controversy as to whether it precedes or follows initiation of the movement (Gerbrandt, Goff, and Smith, 1973; Wilke and Lansing, 1973).

On the whole, the evidence is that Rps are larger if they have an observable outcome. For example, they will tend to be larger when a voluntary button-press triggers a stimulus than when it does not. On the basis of experiments in which they recorded RPs prior to voluntary eye movements in man, Becker, Hoehne, Iwase, and Kornhuber (1973) concluded that the RP was a sign of the general preparation of premeditated voluntary acts and that is only indirectly related to the initiation and motor control of movements.

CHAPTER III
EVENT RELATED POTENTIALS -- MEMORY AND THE ORIENTING RESPONSE

3.1 Event Related Potentials and Memory

Many studies in the literature reporting on the P300 component evaluate the extent to which a memory model, constructed in the brain of a subject as the result of some type of previous experience, alters the features of the evoked potential subsequently observed in that person. The changes in the evoked potential features can be most simply interpreted as the result of a matching process between an internal representation and a subsequent external input (Gomer et al., 1976).

Several studies in the literature address the question of familiarity or recognition almost directly. Courchesne et al., (1975) advanced the hypothesis that differences in scalp distributions in P300 waves reflected ease of recognition of the evoking stimuli. Gomer et al. (1976) reported significant amplitude changes in the average vertex potential after 300 msec, which were evoked by visual presentation of items in a previously memorized list (letters of the alphabet) as compared with potentials evoked by items not previously memorized.

Thatcher (1977) presented subjects with sequences of stimuli consisting of a) a variable number of random dot displays; b) a letter; c) another variable number of random dot displays; and d) a second letter either identical to or mismatching the first letter. Subjects indicated whether the two letters matched. Presentation of the first letter invoked P300 activity (i.e., this is a task relevant event). Upon presentation of the second letter, the P300 invoked by a match was of a significantly different amplitude from that invoked by a mismatch. This effect was seemingly independent of probability, since the probability of either a match or a mismatch was 0.5. Similar results using a match/mismatch design like Tatcher's were reported by Gomer, Spicuzza, and O'Donnel (1976).

Thatcher (1977) interpreted his results as the following: "The response to the match test stimulus reflects both a long-term memory match and a match with the recently activated letter representation" (p. 20). John (1977) has expressed a similar view by proposing that the P300 "is a general wave process reflecting the completion of a fit between external sensory information and internal representational systems" (p. 137). Here P300 is held to be the result of a match between a sensory encoding of the stimulus and an internal neural representation or template.

3.2 Event Related Potentials and the Orienting Response

As already discussed many studies have shown that the presentation of an infrequent and unpredictable stimulus that is comprised of a late positive component (p300) and a slow wave (Squires, Squires and Hillyard, 1975; Squires, Donchin, Herning and McCarthy, 1977; Duncan-Johnson and Donchin, 1977). While the question as to whether P300 is a unitary phenomenon or a manifestation of multiple positive processes corresponding to differing psychological constructs remains to be solved (Pritchard, 1981), one unifying construct that has been proposed for the P300 component is its relationship to the orienting response. Theoretically, the orienting response is evoked whenever a novel stimulus violates certain expectations. According to Sokolov (1963), this means that cortical analyzers have registered a mismatch between an external stimulus and a template or neuronal model constructed from previous experience. In addition, it is predicted that when the same stimulus is presented repeatedly, the orienting response will habituate as a result of the construction of a neuronal model for that stimulus (Sokolov, 1963; Lynn, 1966). An orienting interpretation of P300 is not necessarily in conflict with cognitive interpretations that associate P300 with certain stages of information processing. More recent formulations of the orienting response have also elaborated on the function of orienting within an information processing framework or the multi-stage character of orienting (Kahneman, 1973; Pribram and McGuiness, 1975; Ohman, 1979; more on these studies will be discussed later).

Support for P300 as a component of the orienting response is mainly based on studies that demonstrate that P300 amplitude is inversely related to the subject's expectancy for a stimulus, either as a function of the priori probability of the stimulus, or the specific sequential structure of the preceding stimuli (Squires, Wickens, Squires and Donchin, 1976; Duncan-Johnson and Donchin, 1977; Donchin, 1979). Additional support for an orienting interpretation of P300 comes from experiments in which an increase in P300 amplitude is found as the physical disparity between an infrequent stimulus and a frequent background stimulus increases (Ford et al., 1976); Courchesne, Courchesne and Hillyard, 1978). Finally, it has been shown that the amplitude of P300 to infrequent auditory stimuli decreases over the course of a session when subjects are instructed to ignore these stimuli, which may be interpreted as a sign of habituation (Roth and Kopell, 1973; Roth, 1973).

The orienting construct has also been associated with the slow-wave component of the ERP. As already discussed, this wave is affected by stimulus probability inthe same way as P300, but has a different scalp distribution: it is positive-going on the parietal scalp site, and negative-going on the frontal scalp site. There is evidence that this component may be identified with the slow potential shift that is evoked by the warning stimulus in a CNV paradigm and has been designated the orienting wave or early CNV. The amplitude of this wave strongly depends on the arousal properties of the warning stimulus, such as intensity, modality and novelty, and has therefore been related to the process of alerting or orienting by several authors (Loveless and Sanford, 1975; Gaillard, 1976; Rohrbaugh, Syndulko and Lindsley, 1978; Kok, 1978; Jarveletho, Hari and Sams, 1978; Rohrbaugh, Syndulko and Lindsley, 1979). In all the studies mentioned above, P300 was evoked by infrequent and unpredictable familiar stimuli that were easy to identify or recognize, such as tones or simple verbal stimuli. Also, the short-term changes in P300 waveform, as a result of repeated presentations of infrequent stimulus events, have been left out of consideration since the waveforms were averaged across successive presentations of these stimulus events within a block of trials. In a series of recent experiments Courchesne et al. (1975, 1978) reported a large frontal P300 wave that was found after presentation of task-irrelevant and infrequent-unfamiliar stimuli (different abstract color patterns) that were interspersed among familiar frequent non-target and infrequent target stimuli (numbers). When sub-groups of consecutive presentations of these stimuli were averaged, it was shown that the scalp distribution of P300 was initially frontal, but became parietal with repeated presentation. The amplitude of the frontal P300 to infrequent-unfamiliar stimuli was also larger than the amplitude of the parietal P300 to infrequent-familiar stimuli. These findings are clearly in accord with the orienting response postulate that the amplitude of the response is enhanced when stimulus novelty or degree of mismatch from the neuronal model increases (Friedman, 1978). These results have also raised the question as to whether frontal and parietal P300s are manifestations of different psychological processes, or different aspects of orienting behavior (Courchesne et al., 1978; Roth, 1978; Friedman, 1978). According to Courchesne, the frontal P300 represents the cognitive component of the orienting response that strongly relates to ease of recognition and is emitted whenever formation of a new concept is required. In contrast, he hypothesizes that the parietal P300 to infrequent-familiar non-target stimuli occurs whenever existing concepts are appropriate (Courchesne, 1978). However, Kok and Looren de Jon (1980) point out that in these experiments the unfamiliar stimuli that evoked frontal P300 waveforms also differed in other aspects from the frequent and infrequent-familiar stimuli, such as complexity, significance and pictorial vs. linguistic qualities. As such, it remains doubtful that the frontal P300 merely represents those cognitive components of the orienting response that are related to recognition.

The limitations in the Courchesne et al. experiments (1975, 1978) were addressed by Kok and Looren de Jong (1980). They designed a study to examine the effects of repetition of the same infrequent-familiar and infrequent-unfamiliar stimuli, intermingled with frequent-familiar stimuli, on the waveforms of the evoked response. The same type of abstract geometrical patterns served as stimuli in the three stimulus conditions, but in contrast with the unfamiliar stimuli used on the Courchesne studies, the familiar stimuli were easy to identify or recognize since they had been familiarized by repeated presentations in a separate session of the experiment. No overt response to the stimuli was required, but subjects were instructed to memorize the three types of stimuli. As such, differences between the three stimulus categories were not contaminated by differences in either task relevance or physical characteristics. ERP waveforms that were elicited by the infrequent-familiar and infrequent-unfamiliar stimuli were averaged separately for each presentation of these stimuli across different blocks of trials. In this way, the short-term changes in ERP components, as a function of repetition, could be studied specifically for each successive presentation o these two types of stimuli within a block of trials.

From their study they reported that randomly presented infrequent visual patterns, both familiar and unfamiliar, evoked complex ERP waveforms. The waveforms consisted of a sequence of three components, a P300 wave, a P400 wave and a prolonged slow wave of diminishing positivity. P300 and P400 were most prominent on the central and parietal electrode sites (they recorded from Fz, Cz, Pz, Oz of the International 10-20 system), while the slow wave reached the greatest positivity at the frontal, central and parietal sites. Frequent-familiar patterns evoked only low voltage

P300 waves that peaked with shorter latencies than the P300s to the infrequent stimulus patterns. A principal components analysis was reported as being consistent with visual identification of the three waves in the averaged ERP. In their discussion the authors interpreted their results as being consistent with both orienting and information processing perspectives. A thorough understanding of their procedures is necessary.

In the Kok and Looren de Jong study (1980) three different geometric patterns (frequent-familiar, FF; infrequent-familiar, IF; and infrequent-unfamiliar, IUF) for each of 23 trials were presented to their subjects. Each trial consisted of two blocks B1 and B2. For B1, subjects were shown two stimuli in alternating order 20 times each (40 stimulus presentations). These two stimuli constituted the familiar stimuli used in block 2. An averaged evoked response was recorded for the first and twentieth presentations of each of these two stimuli for B1; for B2, 50 stimulus presentations occurred. One of the two stimuli in B1 was designated the FF stimulus and was randomly presented 40 times; the other stimulus from B1 was designated as the IF stimulus, and was randomly presented five times. A special condition was that an FF stimulus occurred prior to each of the infrequent stimuli (IF, IUF). Averaged evoked responses for the first, third, and fifth presentations of FF, IF, and IUF across the 23 block 2s were reported. However, it must be noted that an average for the first, third and fifth (1-3-5) presentations of the three stimuli across blocks is somewhat misleading. For the IUF stimuli the 1-3-5 average does in fact represent the frequency of appearance of a previously unfamiliar stimulus; for the IF stimuli it represents the 21st-23rd-25th time that that stimulus was actually seen (i.e., as this stimulus was presented 20 times previously in block 1); and for the FF stimuli the 2-3-5 average represents something entirely different. This in fact is an average of the first, third and fifth presentations of an IF stimulus. Two partial block 2 sequences from trials 1 and 2 reported by Kok and Looren de Jong (1980) illustrate the point: trial 1 block 2: FF FF FF IF FF FF IUF FF FF IF FF FF IUF... 50; trial 2 block 2: FF FF IUF FF IF FF FF FF IF FF IUF FF...50. In block 2 for trial 1 the first presentation of FF which precedes the first presentation of IF really represents the 23rd time FF had actually been presented (i.e., 20 times from the preceding block), whereas for block 2 trial 2 it represents the 24th time of actual appearance. Therefore, the 1-3-5 averages reported for the FF stimuli across the 23 block 2s are in fact independent of their actual frequency within a block and vary across blocks.

In discussing their study Kok and Looren de Jong (1980) interpreted their results as revealing several important characteristics of the ERP components. First, infrequent-unfamiliar stimuli evoked components that had a greater amplitude than the components that had a greater amplitude than the components that followed presentation of infrequent-familiar stimuli. The latency of P300 to infrequent unfamiliar stimuli was longer than the latency of P300 to infrequent-familiar stimuli. Second, the data indicated that the amplitudes and latencies of ERP components to infrequent and randomly presented stimuli show a considerable variation with repeated presentations. Even the repetition of infrequent-familiar stimuli was associated with a progressive dimunition of the amplitudes of the three components and a shortening of P300 latency. "This effect cannot be ascribed to general decrease in arousal or habituation to both frequent and infrequent stimuli, since it occurred only with variation of the infrequent stimuli and not with variation of the frequent-familiar stimuli that preceded the infrequent stimuli" (Kok and Looren de Jong, 1980, p. 184). However, recall from the detailed examination of their procedures that the the reported averages from which these comparisons were based (i.e., 1-3-5) represent averages obtained from three different stimulus frequencies. For the IUF stimuli across the 23 block 2s does in fact represent the first time this class of stimuli was presented to their subjects; for the IF stimuli the average for the first presentation actually represents an average across block 2s for the 21st presentation of this class of stimuli; and for the FF stimuli, an average for the first presentation of FF stimuli, which directly preceded IF stimuli, represents the average for the 23rd presentation in trial 1 block 2, 24th presentation of trial 2 block 2, etc. (from Fig. 1, p. 171, Kok and Looren de Jong, 1980). Therefore, habituation would be expected to contribute to diminishing amplitudes.

A third characteristic which Kok and Looren de Jong (1980) found in their data was that temporal effects due to stimulus repetition were enhanced when infrequent-unfamiliar stimuli were presented to the subject. The difference in amplitude of P300 and the slow wave to infrequent-unfamiliar and infrequent-familiar stimuli was greatest during earlier presentations of these stimuli and then declined during presentations. This effect was most pronounced for the slow wave. The positivity of the slow wave of the first presentation of the unfamiliar stimuli was approximately 120% higher than the amplitude of the slow wave evoked by the first presentation of the familiar stimuli and decreased rapidly with successive presentations. Since the decline of slow wave positivity with repeated presentations of the familiar stimuli was much slower, the difference in amplitude of the slow wave elicited by familiar and unfamiliar stimuli had almost completely disappeared by the third presentation. Thus, it was concluded that with repeated presentations of unfamiliar stimuli, the waveforms that were evoked by these stimuli gradually became more similar to the wave forms that were associated with familiar stimuli (Kok and Looren de Jong, 1980).

There have been several reports of decreases in amplitude of both the earlier and later components of the ERP with stimulus repetition (Ritter et al., 1968; Roth, 1973; Rust, 1977; Jarviletho et al., 1978). These effects were found in conditions in which the subjects attended passively to, or ignored the stimuli. These findings may be interpreted as a sign of non-specific changes in general alertness, habituation or modifications of earlier stages or processing, related to encoding of physical stimulus characteristics. In Kok and Looren de Jong's experiment, however, active cognitive processing of the perceptual characteristics of the infrequent stimuli were required. Subjects were instructed to memorize the three geometric stimuli. Under the assumption that in task relevant conditions later components of the ERP, such as P300 and the slow wave, are manifestations of later stages of processing related to cognitive evaluation of the incoming stimuli (Donchin, Ritter and McCallum, 1978; Donchin, 1979), the changes in the later components of the ERP with repeated presentations of the stimuli in Kok and Looren de Jong's study were interpreted as manifestations of specific alterations of cognitive processes engaged on each succeeding stimulus event, rather than non-specific changes in general alertness, habituation or sensory adaptation to physical stimulus characteristics (Kok and Looren de Jong, 1980). However, as previously discussed, this conclusion cannot be accepted without some reservation.

An important issue that can be raised in connection with Kok and Looren de Jong's results is the question of whether the multiple positive components are related to the same unitary process or distinct processes. Their data showed that P300, P400 and the slow wave were affected almost identically by stimulus frequency, stimulus familiarity and stimulus repetition. Orienting response theory would predict a larger amplitude response to infrequent and unpredictable stimuli that were also more novel or unfamiliar, and a progressive dimunition of the amplitude of the response with repeated presentation of novel stimuli (Lynn, 1966). In the opinion of the authors, the most parsimonious interpretation of their results was that all the components of the ERP were part of the same orienting response.

The interpretation is not necessarily incompatible with cognitive interpretations based on information processing theory. Recent formulations of orienting have stressed the dynamic, information processing character of the orienting response. According to Sokolov (1969) the neuronal model acts not only as a passive, selective filter mechanism, but also as an information regulator that constantly undergoes revision in order to account for changing stimulus characteristics, and extrapolates the future value of a stimulus. It has been suggested that orienting involves two states of processing: a detection of mismatch, and the subsequent continued processing that is necessary in order to carry out revisions of the neuronal model or patterned structure of memory traces. For instance, Kahneman (1973) describes the orienting response in terms of a recursive process in which preliminary evaluations of novelty or significance cause an allocation of effort for further processing. Like Kahneman, Pribram and McGuiness (1975) suggest a continued processing, denoted as context updating, that follows stimulus mismatch and also requires mental effort. Recently, Ohman (1979) has proposed that the physiological concomitants of the orienting response is a prerequisite for learning, because information can only be stored in long-term memory through rehearsal in a central processing channel.

In further discussion of their study, Kok and Looren de Jong (1980) speculated that the sequency of positive components was related to the two stages of processing that underlie orienting described above. They pointed out that subjects were instructed to memorize stimulus patterns that belonged to three different categories. On this basis it was assumed that in their paradigm preliminary categorization of the stimuli was dissociated in time for subsequent continued processing. Within this context continued processing was conceived of as a cortical process which is associated with strengthening of the memory trace, and the gradual build-up of representations of perceptual stimulus characteristics. It was also hypothesized that this process is associated with a momentary increase in mental effort in consequence of rapidly decaying traces in short-term memory. As such, the change in P300 was seen as a manifestation of the preliminary stage of stimulus categorization, and the change inthe slow wave as a manifestation of continued processing of stimulus characteristics that occurs after stimulus categorization. These interpretations of P300 and the slow wave served to clarify the different change in paterns that were found for these components with repetition of unfamiliar and familiar stimuli in the Kok and Looren de Jong study (1980).

The difference in amplitude and latency of P300 to unfamiliar and familiar stimuli was small or even absent on the first presentation and increased on the second presentation of these stimuli. This observation was explained by assuming that on the first presentation unfamiliar stimuli could be classified easily as unfamiliar since these stimuli were completely unknown and consequently belonged (like the familiar stimuli) to a distinct stimulus category. However, on the second presentation classification of the unfamiliar stimuli was more difficult, since the subjects probably no longer classified these stimuli as unfamiliar, but the internal representation or memory trace of these stimuli was still relatively weak in comparison with the familiar stimuli (Kok and Looren de Jong, 1980). Finally, the decrease of P300 latency with stimulus repetition was seen as a sign of stimulus categorization which becomes gradually faster and more automatic, in consequence of a progressive strengthening of the internal representation. In contrast with P300 (and P400) the difference in amplitude of the slow wave to unfamiliar and familiar stimuli was greatest on the first presentation and then declined linearly with successive presentations of these stimuli. It was suggested that the slow wave specifically reflects mental effort which is allocated to rehearsal of perceptual stimulus characteristics in short-term memory, and which has an inverse relationship with the strength of the memory trace.

These interpretations of P300 and the slow wave as signs of respectively stimulus categorization and activation of short-term memory processes remain speculative, since in the Kok and Looren de Jong (1980) experiment no behavioral measures (such as recognition or memory indices) were collected. However, support for Kok and Looren de Jong's interpretation of P300 is consistent with the notion that P300 latency reflects stimulus evaluation time rather than the operation of the later stages of processing (Kutas, McCarthy and Donchin, 1977; Donchin, 1979). These authors found an inverse correlation between the slow wave positivity and the probability of correct recognition in a word-matching task and suggested that the amplitude of the slow wave indicated the strength of the memory trace. In addition, the finding that slow wave positivity is specifically related to processing of infrequent visual stimuli that are difficult to recognize is also corroborated by the data obtained in a recent experiment by Kok (1979). This experiment showed that infrequent visual stimuli that were degraded evoked longer reaction times, and slow waves of greater positivity than infrequent undegraded stimuli. In a recent review on the connections between slow cortical potentials and orienting, Loveless et al. (1979) has proposed that slow wave positivity may indicate inhibition of irrelevant motor activity. In this report it was also suggested that the marked positivity of this wave produced by visual stimuli may reflect an inhibition of eye movements, since visual stimuli place a premium on the suppression of eye movements. This hypothesis is consistent with the view expressed by Kahneman (1973) that a temporary inhibition of on-going activities is one of the salient features of an orienting response to novel stimuli, and that this inhibition facilitates the processing of the novel stimulus. If these assumptions are correct, the large positivity of the slow wave following the presentation of unfamiliar stimuli found in the Kok and Looren de Jong study (1980) may be viewed as a sign of enhanced inhibition of irrelevant (occulomotor) activities. It was hypothesized by the authors that this process accompanies an increase of perceptual processing demands and facilitates continued perceptual processing of these stimuli.

The P400 component, which was similar to P300, both in scalp distribution and in variation from experimental manipulations, was interpreted by Kok and Looren de Jong

(1980) as related to the same processes that determined P300. However, the effect of stimulus familiarity was much stronger for P400 than for P300. If it is assumed that unfamiliar stimuli required more perceptual processing effort, then the P400 component may be interpreted as a manifestation of a demand or call for continued processing of unfamiliar stimuli that follows categorization of unfamiliar stimuli (p300), and precedes continued perceptual processing of these stimuli (slow wave). In this view, P400 was interpreted by the authors as a sign of utilization of specific stimulus information rather than stimulus categorization. This interpretation is consistent with Stuss and Picton's (1978) interpretation of P400. These authors suggested that in stimulus paradigms in which perceptual categorizations are rather simple, but the utilization of stimulus utilization are dissociated in time, as evidenced by the separate P300 and P400 components of the ERP.

In summary, it was concluded by Kok and Looren de Jong (1980) that their data demonstrated that stimulus frequency, stimulus familiarity and stimulus repetition had a strong effect on the latency of P300, and the amplitude of P300, P400, and the slow wave. With repeated presentation of the same infrequent-unfamiliar stimulus, ERP waveforms gradually became more similar to the waveforms that were elicited by the infrequent stimuli. This effect was most pronounced for the slow positive wave. It was suggested by the authors that these components may be related to different stages of information processing that play a role during orienting.

3.3 Summary and Comments on Event Related Potentials

Perhaps the most important feature to emerge from the many studies of event related potentials and performance is that ERPs do not merely represent those psychological processes which manifest themselves in overt behavioral performance. The contrary, the evidence points to the fact that ERP components systematically reflect changes of brain stage accompanying the processing and evaluation of incoming information, the initiation of action and the establishment of sets or dispositions to act. In addition to traditional behavioral measures, ERPs provide a new perspective to the investigation of human cognitive measures, but rather as an additional means by which researchers can add to our understanding of the systems and mechanisms through which we become aware and interact with our environment (McCallum, 1978). The use of event related potentials in the investigation of cognitive processes, such as memory, has demonstratedly allowed experimenters more specificity in examining such areas as the relationship between mental effort, information processing, and the orienting response. However, as with behavioral measures used to study pictorial memory, the use of event related potentials has focused primarily upon measuring the processes and products of retrieval from memory. The learning and consolidation of new information into long-term memory has received little attention.

CHAPTER IV
STATEMENT OF THE QUESTION

4.1 Three Hypotheses

Throughout the introduction of this dissertation it was suggested that knowledge of the learning and processing of pictorial stimuli into long-term memory would provide additional, potentially useful information to our current explanations of why pictures are better remembered than their verbal counterparts (Appendix 1). Furthermore, an understanding of these processes would provide a new perspective to current questions regarding recognition processes for facial vs. other pictorial stimuli (Appendix 2). However, before these questions can be addressed, a methodology providing the necessary specificity is needed.

As previously discussed, studies of event related potentials indicate that ERPs may reflect changes in brain statement which accompany the processing and evaluation of incoming information. From studies such as Kok and Looren de Jong (1980), which related the orienting response to the processing of infrequent-familiar and infrequent-unfamiliar visual stimuli, a method is suggested from which the processing of pictorial stimuli into long-term memory may be examined. In their study they reported that unfamiliar stimuli were differentiated by evoked responses from previously memorized familiar stimuli, without traditional performance measures (i.e., reaction time, accuracy). Furthermore, Kok and Looren de Jong (1980) reported that infrequent unfamiliar stimuli evoked components of greater amplitude than the components which were elicited from the presentation of infrequent-familiar stimuli. These results were interpreted as being part of the same orienting response, and not inconsistent with cognitive interpretations based on information processing theory.

These results suggest that if unfamiliar visual stimuli can be differentiated from familiar stimuli on the basis of their evoked response in a task requiring no behavioral performance (RT or accuracy), then a correlate of the learning process, which subsequently led to that differentiation, should also be measurable.

From Kok and Looren de Jong (1980), the orienting response can be conceived of as consisting of two states: a passive, selective filter mechanism; and an information regulator that constantly undergoes revision in order to account for changing stimulus characteristics and extrapolates the future value of a stimulus (Sokolov, 1969). As previously discussed, this two-stage process of orienting was described by Kahneman (1973) as a recursive process, by Pribram and McGuiness (1975) as context updating, and by Kok and Looren de Jong (1980) as stimulus categorization and continued processing. Within this context differentiating predictions were made for P300, P400, and slow wave evoked potential components of unfamiliar pictorial stimuli, and pictorial stimuli which were learned through repeated presentation across experimental trials (i.e., familiar stimuli).

4.2 P300 Hypothesis

Following Kok and Looren de Jong (1980), P300 was assumed to be a manifestation of the preliminary state of stimulus categorization. As such, it was predicted that in a comparison between familiar and unfamiliar stimuli, no difference in P300 would be expected for the first presentation, but that with comparisons across repeated trials, P300 amplitude for familiar stimuli should decrease. This prediction is based on the assumption that stimulus categorization becomes gradually faster and more automatic, in consequence of a progressive strengthening of the internal representation in long-term memory (Kok and Looren de Jong, 1980).

4.3 P400 Hypothesis

By assuming that unfamiliar stimuli would require more perceptual processing effort, and that P400 can be interpreted as a manifestation of a demand or call for continued processing of unfamiliar stimuli (Kok and Looren de Jong, 1980), it was expected that the P400 component would be greater for unfamiliar stimuli than familiar stimuli, and that in the process of learning, P400 amplitude for the familiar stimuli would show dimunition across trials. That is, as previously unfamiliar stimuli become learned through repetition across trials, the P400 component which is elicited by these stimuli was predicted to decrease. Furthermore, the P400 component elicited from unfamiliar stimuli was expected to show no such a dimunition across trials.

4.4 Slow Wave Hypothesis

Kok and Looren de Jong (1980) proposed that continued processing can be conceived of as a cortical process which is related to the strengthening of the memory trace, and the gradual build-up of perceptual stimulus characteristics; associated with continued processing is the idea that momentary increases in mental effort are a consequence of rehearsal of rapidly decaying traces in short-term memory. These authors further proposed that the slow wave evoked potential component reflects the allocation of mental effort to the rehearsal of perceptual stimulus characteristics in short-term memory, and that this allocation of mental effort to the rehearsal of perceptual stimulus characteristics in short-term memory, and that this allocation is inversely related to the strength of the memory trace in long-term memory. Given these assumptions, it was predicted that slow wave activity during the learning process would show greater amplitude during the first few presentations (i.e., when the stimulus was considered unfamiliar), and that with subsequent presentations slow wave amplitude would show a relative decrease in amplitude.

In previous studies short-term changes in evoked potential components to familiar and unfamiliar stimuli, as the result of repeated stimulus presentations, have been left out of consideration since the waveforms were averaged across successive presentations of these stimuli. In the Kok and Looren de Jong (1980) study an attempt was made to examine short-term changes in evoked potential components. However, as previously discussed (Chapter III, 3.2), serious reservations in the methods used in that study necessarily limit the obtained results and their subsequent interpretation. The methods and procedures developed in the present study allow the researcher a means by which to examine short-term changes in the evoked response associated with the learning of complex pictorial stimuli.

CHAPTER V
METHODS AND PROCEDURES

5.1 Subjects

Twenty right-handed male students with uncorrected vision form the University of Florida, ages 18 to 25 years, were paid a fee to serve as subjects. Subjects were informed as to the nature of the experiment; a consent form was explained and signed; and after the study was completed, the hypotheses and findings were made available.

5.2 Stimulus Selection and Procedures

Two hundred fifty (2 inch by 2 inch) colored landscape slides (complex pictorial stimuli) were equated for log foot lamberts relative to a blank slide (see Appendix 3). Two hundred slides which were within 30% of 1115 log foot lamberts (the mean value from the 250 slides) were randomly assigned to 1 to 5 sets (F_1, UF_1, UF_2, UF_3, UF_4,) with 40 slides assigned to each set.

Each subject was presented with five experimental sessions (also called trials) consisting of two sets (80 slides) per session. Set F_1 was designated as the familiar set and was presented once in each of the five sessions; sets UF_1, UF_2, UF_3, and UF_4 were designated as the unfamiliar sets and were presented in sessions 1 and 2. For each of the five sessions a different random sequence for the 80 slides was used (see Appendix 4). A total of 200 different slides were used, and in accordance with the sequencing presented in Appendix 4, this resulted in 400 stimulus presentations. The slides were presented in a Singer Caramate II projector, back lit by a 150 watt lamp at 120 volts, from a distance of 165 cm., in an electrically isolated room with lighting measured at .30 foot-candles using a Model 40A light-measuring instrument from United Detector Technology. Subjects were placed in the experimental room 15 minutes before the start of the first session to allow adaptation to room lighting and noise. The duration of the stimulus presentation was 400 milliseconds, with an interstimulus interval which randomly varied between 3 and 4 seconds; all slides subtended a visual angle of 7.9 degrees. At the beginning of each session subjects were instructed to fixate upon a dot in the center of the screen and to memorize the slides that were presented. Each session took approximately 7 minutes to run, and a 5-minute break was given between sessions 3 and 4. The entire procedure required approximately 105 minutes.

Following a two week interval the experimental procedure was identically repeated. The first experimental procedure was designated F-SPEC, on time one (T1). The second experimental procedure following the two-week interval was designated B-SPEC, or time two (T2). Three subjects failed to return after the two-week interval, total N = 17.

5.3 Evoked Response Recording Procedure

Silver-Silver chloride cup electrodes and paste (Beckman) were used to record the EEG monopolarly, from scalp positions C_3, C_4, and P_z of the International 10-20 electrode system, referenced to linked mastoids. Impedance never exceeded 2 K. ohms, as measured by a d.c. impedence tester (IMA Electronics). A diagonal EOG channel was also collected for the detection and subsequent exclusion of eye movement artifact from the collected data. The data was digitized at 125 samples/second/channel (8 msec sampling interval on 1,000 Hz sampling frequency over the 4 channels). The amplifiers had a bandwidth from 1 to 50 Hz, with 50% attentuation at 1 and 50 Hz.

Each subject was seated in an adjustable ophthalmic chair in an electrically shielded and light-proof room (Faraday Room). Ventilating blowers produced a steady 62 dB noise level (General Radio 1551-A) to mask equipment and extraneous noise. Solid state d.c.-powered differential amplifiers were placed inside the shielded room near the subject, enabling the use of short electrode leads (Microdot).

Prior to the conduction of the experiment on each subject, the operator performed a pre-operational check on the equipment. A 10 microvolt, 10 Hz calibrate signal was connected to the input of all the EEG amplifiers. The operator verified proper operation of the amplifiers. The operator proper operation of the amplifiers by observing each channel on an oscilloscope and by collecting and digitizing 512 samples from each channel which were displayed on a 5111 Tektronix storage scope. Photic evoked response (VER) trials were collected using a Grass Instruments xenon photo stimulator. The VER trials were used to calculate an average evoked response that was displayed on a Tektronix 564 storage oscilloscope and visually inspected for proper shape and magnitude. An invalid VER signal usually indicated amplifier malfunction or improper electrode connection.

Two averaged evoked responses for each of the four channels (C_3, C_4, P_z, EOG) were obtained for each of the five sessions, one for each set of 40 slides. These evoked potentials were averaged from the first 30 acceptable responses from each set of 40 slides (40 familiar slides, F_1; and 40 unfamiliar slides from sets UF_{1-4}). Individual slide presentations with eye movement artifact were excluded from these averages.

CHAPTER VI
ANALYSIS AND RESULTS

6.1 Precautions in Averaging Evoked Responses

An evoked response is defined as the combination of the stimulus evoked activity of the brain and the noise, which is brain activity not related to the stimulus, together with interferences from non-neural sources. In this context, "signal" is synonymous with "stimulus evoked activity" and "noise" with the remainder of the observed response. Presumably, to some extent the signal is deterministically related to the experimental conditions and thus can ultimately be controlled by the experimenter. Noise appears to be random in behavior and essentially cannot be controlled by the experimenter and interferes with observation of the signal.

Averaging across ERPs will attenuate the noise but not the signal provided that the signal is synchronized in time to the stimulus; the signal waveshape is relatively invariant; and the signal and the noise do not interact with each other and sum linearly to produce the observed evoked response.

The degree of noise reduction achievable depends upon the statistical properties of the noise. If the noise contributions to successive ERPs are statistically independent of one another, then the noise will tend to cancel when averaged (John, Ruchkin, Vidal, 1978). The degree of attenuation, as measured by the root mean square (rms) level of the residual noise, will then be inversely proportional to the square root of the number of ERPs in the sample. For example, if the ratio of the rms signal level to rms noise level os the raw ER is 1:2 and 100 evoked responses are averaged together, the resulting rms signal to residual noise level will be 5:1.

If the time intervals between stimuli are sufficiently large, the noise activity associated with each epoch following a stimulus will be uncorrelated with noise from other epochs (John, Ruchkin, Vidal, 1978). As the time between onset from the first to the second stimuli was approximately 3 seconds in the present study, it was therefore reasonable to assume that noise from other epochs was uncorrelated.

Problems may also arise if ERPs persist beyond the time of occurrence of subsequent stimuli. With periodic stimuli the overlapping late components will be time-locked to the subsequent stimuli. Such overlapped late components will not be cancelled by averaging and so will appear as spurious short-latency components of the extracted signal. However, interference due to rhythmic noise and overlapped late components may be attenuated if the stimuli are suitably aperiodic (Ruchkin, 1965). The overlapping components and rhythmic noise will then be asynchronous with respect to the stimuli, and effective cancellation can occur. In the present study the interstimulus interval was randomly set between 3 and 4 seconds, and as such, any potential rhythmic noise was assumed to cancel via the averaging process.

6.2 Correlations Between Amplitude and Variability

Callaway (1975) pointed out that the average evoked potential amplitude and evoked potential variability are related in two ways: one tending to produce a positive correlation between measures of variability and amplitude; the other tending to produce a negative correlation. Just which correlation will be found depends on the particular measures of variability that one selects and the particular experimental design used. However, Callaway (1975) further discusses a means by which to free the data from the correlation with amplitude caused by amplification or attenuation constants. To remove the effects of amplitude the data may be normalized (i.e., set the mean to zero and divide each averaged evoked response by the standard deviation). In this way a Pearson product-moment correlation coefficient can be reliable used as a descriptive index of the similarity or dissimilarity between ERPs with effects of amplitude held constant.

6.3 Analysis of the Variables

As previously discussed (Chapter V, 3.6), the average evoked response for each class of stimuli (familiar and unfamiliar slides) was obtained for each session (1-5), electrode site (C3, C4, PZ), time (time one, time two), and subject by averaging the first 30 acceptable responses.

After the data were transformed into Z scores (Chapter VI, 6.2), individual subject averages for the variables N100 mean, P300 mean, P400 peak, negative component, and slow wave mean (Chapter VI, 6.4) were obtained by class, session, time and electrode site. These individual subject averages for the stated variables were then analyzed by channel (C3, C4, PZ) using a repeated measures analysis of variance, with three within-subject factors of session, class and time, having five, two, and two levels respectively (see Table 1).

TABLE 1

WITHIN-SUBJECT FACTORS AND LEVELS FOR THE REPEATED MEASURES ANALYSIS OF VARIANCE

Within-Subject Factors	Levels
1. Session :	5 levels (sessions 1-5)
2. Class :	2 levels (familiar, unfamiliar)
3. Time :	2 Levels (time 1, T1, F-SPEC; time 2, T2, B-SPEC)

6.4 The Variables Measured and Analyzed

Where possible a measurement of mean microvolt response (an average over a specified millisecond interval) is desirable over a measurement of peak microvolt response (a point in a specified millisecond interval); the reason being that a measurement based on several vs. a single data point is more reliable. With early components, where the latency of response across subjects tends to be less variable (on the millisecond axis), taking an average over a specified millisecond interval is appropriate. However, with later components, such as P300 and P400, measurement becomes more complicated. For example, the P300 of one subject may be at 220 milliseconds, whereas for another it may occur at 350 milliseconds.

The problem that can arise is that in setting the interval to be averaged too small the P300 response may be omitted in the averaging process. Conversely, setting the interval too large may result in averaging other than P300 components. To the extent that variability in latency of a given component across subjects is minimal on the millisecond axis, a mean response is desirable and appropriate. To the extent that variability in latency exists, peak measurement is typically employed.

6.4.1 N100 Mean

The N100 component is a negatively peaking evoked potential component which typically obtains maximum negative peak amplitude at approximately 75 (±25) milliseconds. The N100 component, as with other exogenous components (see Chapter II, 2.5), is associated with the physical aspects of the stimuli.

In the present experiment because of the low variability in latency of the N100 component across subjects, the mean response from 50 to 100 milliseconds was obtained (see Figure 1).

6.4.2 P300 Mean

The P300 component (see Chapter II, 2.3.2; Chapter III, 3.2) in the present experiment was measured by mean. The variability in the latency of this response typically requires peak measurement. In the present experiment, however, very little latency was observed across subjects. As such, a mean microvolt measurement was obtained between 250 and 350 milliseconds (see Figure 1).

6.4.3 P400 Peak

The P400 component (see Chapter III, 3.2) in the present experiment was measured by taking the peak microvolt amplitude occurring between 350 and 550 milliseconds. The decision to use peak measurement for the P400 component was necessitated by the relationship of the P400 and P300 components, and not due to variability in latency across subjects for the P400 component (see Figure 1).

6.4.4. Negative Component

Examination of individual evoked responses revealed a negatively peaking component occurring between 440 and 680 milliseconds. The main characteristic of this component was that 13 of the 17 subjects of time one (session 5) and 14 out of 17 subjects at time two (session 5) had greater negative amplitude for the familiar class of stimuli than for the unfamiliar stimuli. A conservative measurement of this component was decided upon, and the mean microvolt amplitude from 440 to 680 milliseconds was obtained.

6.4.5 Slow Wave Mean

The slow wave (see Chapter II, 2.3.3; Chapter III, 3.2) in the present experiment was measured by taking the mean amplitude of the evoked response which occurred between 750 and 850 milliseconds (see Figure 1).

6.5 Results from the Repeated Measures Analysis of Variance

The results and follow-up analyses from the repeated measures analysis of variance performed on the variables N100 mean, P300 mean, P400 peak, negative component mean, and slow wave mean are presented in tables 2-16, and in appendix 5, tables 17-42.

The data for the three subjects who completed the experimental procedure at time one, but not time two, were examined and found not to be appreciably different from the other seventeen subjects. These data were not included in the analyses for time one, thereby allowing comparisons and conclusions drawn from time one and time two to be based upon the same subject.

6.5.1 Results for the N100 Component

The mean microvolt amplitudes by time, session and class for each of the three electrode channels (C3, C4, PZ) are presented in appendix 5, tables 17, 19, and 11. No significant interaction effects were obtained for any of the three electrode channels (tables 2, 3, 4). A significant main effect due to session was obtained for channels C3 and C4. The follow-up analyses (Duncan's multiple range test) for the main effects due to session found for channels C3 and C4 are presented in appendix 5, tables 18 and 20.

TABLE 2

RESULTS AND FOLLOW-UP ANALYSIS FROM A REPEATED
MEASURES ANALYSIS OF VARIANCE PERFORMED ON
THE MEAN AMPLITUDE OF THE N100 EVOKED
POTENTIAL COMPONENT RECORDED AT
CHANNEL C3, N = 17

Main Effect	Mean Microvolt Amplitude	*p* Value
Session	= 4.4	*p* = 0.004**
Class	F = 4.4 UF = 4.4	*p* = 0.98
Time	TI = 3.3	*p* = 0.33
Interaction Effect		
Session by Class		*p* = 0.78
Session by Time		*p* = 0.45
Class by Time		*p* = 0.53
Session by Class by Time		*p* = 0.89

**Significant at the 0.005 level.

The main effect due to session was further analyzed using a Duncan's multiple range test, with same letter groupings (A, B, C) not being significantly different (alpha = 0.05), (see Appendix 5, Table 18).

TABLE 3

RESULTS AND FOLLOW-UP ANALYSIS FROM A REPEATED MEASURES ANALYSIS OF VARIANCE PERFORMED ON THE MEAN AMPLITUDE OF THE N100 EVOKED POTENTIAL COMPONENT AT CHANNEL C4, N = 17

Main Effect	Mean Microvolt Amplitude	p Value
Session	= -4.5	$p = 0.02$*
Class	F = -5.0	$p = 0.40$
	UF = 4.0	
Time	T1 = -5.3	$p = 0.58$
	T2 = -3.7	
Interaction Effect		
Session by Class		$p = 0.70$
Session by Time		$p = 0.16$
Class by Time		$p = 0.96$
Session by Class by Time		$p = 0.90$

*Significant at the 0.05 level.

The main effect due to session was further analyzed using a Duncan's multiple range test, with same letter groupings (A, B) not being significantly different (alpha = 0.05), (see Appendix 5, Table 20).

TABLE 4

RESULTS AND FOLLOW-UP ANALYSIS FROM A REPEATED MEASURES ANALYSIS OF VARIANCE PERFORMED ON THE MEAN AMPLITUDE OF THE N100 EVOKED POTENTIAL COMPONENT RECORDED AT CHANNEL PZ, N = 17

Main Effect	Mean Microvolt Amplitude	*p* Value
Session	= -25.6	*p* = 0.28
Class	F = -26.5	*p* = 0.09
	UF = -24.7	
Time	T1 = -27.7	*p* = 0.09
	T2 = -23.5	
Interaction Effect		
Session by Class		*p* = 0.31
Session by Time		*p* = 0.30
Class by Time		*p* = 0.75
Session by Class by Time		*p* = 0.28

6.5.2 Results for the P300 Component

The mean microvolt amplitudes by time, session and class for each of the three electrode channels are presented in appendix 5, tables 22, 24, and 26. Session by class interactions were the only significant interaction effects obtained for the three channels (appendix 5, tables 23, 25, and 27). The follow-up analyses for the session by class interactions for the three channels are presented in tables 5, 6, and 7. No significant differences between the two classes of stimuli (familiar, and unfamiliar) were obtained for sessions 1 and 2. The amplitude for the P 300 component to the familiar class of stimuli was found to be significantly less than the amplitude of the P300 component to the unfamiliar class of stimuli for sessions 3, 4 , and 5 (tables 5, 6, and 7), with one exception. At channel PZ, session 4, no significant difference between the two classes of stimuli was obtained.

TABLE 5

RESULTS FORM A REPEATED MEASURES ANALYSIS OF VARIANCE PERFORMED ON THE SESSION BY CLASS INTERACTION, P300 MEAN, CHANNEL = C3

Session	Mean Microvolt Amplitude by Class	*p* Value
1	F = 26.4	*p* = 0.48
	UF = 24.9	
2	F = 22.6	*p* = 0.55
	UF = 21.4	
3	F = 20.4	*p* = 0.03*
	UF = 24.4	
4	F = 19.5	*p* = 0.01*
	UF = 23.9	
5	F = 19.2	*p* = 0.05*
	UF = 23.2	

*Significant at the 0.05 level.

TABLE 6

RESULTS FORM A REPEATED MEASURES ANALYSIS OF VARIANCE PERFORMED ON THE SESSION BY CLASS INTERACTION, P300 MEAN, CHANNEL = C4

Session	Mean Microvolt Amplitude by Class	_p_ Value
1	F = 21.5	_p_ = 0.96
	UF = 21.6	
2	F = 16.0	_p_ = 0.92
	UF = 15.8	
3	F = 13.9	_p_ = 0.04*
	UF = 18.8	
4	F = 14.1	_p_ = 0.03*
	UF = 18.0	
5	F = 12.4	_p_ = 0.002**
	UF = 18.1	

*Significant at the 0.05 level.

**Significant at the 0.005 level.

TABLE 7

RESULTS FORM A REPEATED MEASURES ANALYSIS OF VARIANCE PERFORMED ON THE SESSION BY CLASS INTERACTION, P300 MEAN, CHANNEL = PZ

Session	Mean Microvolt Amplitude by Class	p Value
1	F = 1.5	p = 0.26
	UF = 0.04	
2	F = -3.4	p = 0.81
	UF = -2.8	
3	F = -6.4	p = 0.008*
	UF = 0.6	
4	F = 3.0	p = 0.12
	UF = 1.3	
5	F = -7.2	p = 0.02*
	UF = -0.9	

*Significant at the 0.05 level.

6.5.3 Results for the P400 Component

The mean microvolt amplitudes by time, session and class for the three electrode channels are presented in appendix 5, Tables 28, 30, and 32. The session by class interactions were the only significant interaction effects for all three channels (appendix 5, tables 29, 31, and 33). The follow-up analyses for the session by class interactions for the three channels are presented in tables 8, 9 and 10. No significant differences between the two classes of stimuli were obtained for sessions 1, 2 and 3. The amplitude of the P400 component to the familiar class of stimuli was significantly less than the amplitude of the P400 component to the unfamiliar class of stimuli for sessions 4 and 5 (tables 8, 9, 10), with one exception. At channel C4, session 5, no significant difference between the two classes of stimuli was obtained.

TABLE 8

RESULTS FROM A REPEATED MEASURES ANALYSIS OF VARIANCE PERFORMED ON THE SESSION BY CLASS INTERACTION, PEAK P400 MEAN, CHANNEL = C3

Session	Mean Microvolt Amplitude by Class	_p_ Value
1	F = 1.1	_p_ = 0.21
	UF = 0.7	
2	F = 1.1	_p_ = 0.66
	UF = 1.0	
3	F = 0.6	_p_ = 0.62
	UF = 0.7	
4	F = 0.4	_p_ = 0.02*
	UF = 1.3	
5	F = 0.7	_p_ = 0.05*
	UF = 1.2	

*Significant at the 0.05 level.

TABLE 9

RESULTS FROM A REPEATED MEASURES ANALYSIS OF VARIANCE PERFORMED ON THE SESSION BY CLASS INTERACTION, PEAK P400 MEAN, CHANNEL = C4

Session	Mean Microvolt Amplitude by Class	_p_ Value
1	F = 0.1	_p_ = 0.19
	UF = -0.3	
2	F = -0.2	_p_ = 0.41
	UF = 0.1	
3	F = -0.4	_p_ = 0.36
	UF = -0.1	
4	F = -0.5	_p_ = 0.01*
	UF = 0.3	
5	F = -0.3	_p_ = 0.10
	UF = 0.3	

*Significant at the 0.05 level.

TABLE 10

RESULTS FROM A REPEATED MEASURES ANALYSIS OF VARIANCE PERFORMED ON THE SESSION BY CLASS INTERACTION, PEAK P400 MEAN, CHANNEL = PZ

Session	Mean Microvolt Amplitude by Class	p Value
1	F = 0.0	p = 0.30
	UF = -0.4	
2	F = -0.1	p = 0.57
	UF = -0.3	
3	F = -0.5	p = 0.54
	UF = -0.3	
4	F = -0.8	p = 0.005**
	UF = 0.2	
5	F = -0.9	p = 0.0003**
	UF = 0.3	

**Significant at the 0.005 level.

6.5.4 Results for the Negative Component

The mean microvolt amplitudes by time, session and class for the three electrode channels are presented in appendix 5, tables 34, 36, and 38. The session by class interactions were the only significant interaction effects for all three channels (appendix 5, tables 35, 37 and 39). The follow-up analyses for the session by class interactions for the three channels are presented in tables 11, 12, and 13. No significant differences between the two classes of stimuli were obtained for sessions 1, 2 and 3. The amplitude of the negative component to the familiar class of stimuli was significantly greater than the amplitude of the negative component to the unfamiliar class of stimuli for sessions 4 and 5 (tables 11, 12, and 13).

TABLE 11

RESULTS FROM A REPEATED MEASURES ANALYSIS OF VARIANCE PERFORMED ON THE SESSION BY CLASS INTERACTION, NEGATIVE COMPONENT MEAN, CHANNEL = C3

Session	Mean Microvolt Amplitude by Class	_p_ Value
1	F = -1.8	_p_ = 0.16
	UF = -4.5	
2	F = -2.3	_p_ = 0.93
	UF = -2.4	
3	F = -4.2	_p_ = 0.25
	UF = -2.0	
4	F = -5.9	_p_ = 0.003*
	UF = -1.3	
5	F = -4.2	_p_ = 0.02*
	UF = -0.1	

*Significant at the 0.05 level.

**Significant at the 0.005 level.

TABLE 12

RESULTS FROM A REPEATED MEASURES ANALYSIS OF VARIANCE PERFORMED ON THE SESSION BY CLASS INTERACTION, NEGATIVE COMPONENT MEAN, CHANNEL = C4

Session	Mean Microvolt Amplitude by Class	p Value
1	F = - 9.3	p = 0.47
	UF = -11.0	
2	F = -11.1	p = 0.99
	UF = -11.1	
3	F = -12.8	p = 0.24
	UF = -10.0	
4	F = -14.3	p = 0.01*
	UF = - 9.6	
5	F = -13.3	p = 0.01*
	UF = - 8.2	

*Significant at the 0.05 level.

TABLE 13

RESULTS FROM A REPEATED MEASURES ANALYSIS OF VARIANCE PERFORMED ON THE SESSION BY CLASS INTERACTION, NEGATIVE COMPONENT MEAN, CHANNEL = PZ

Session	Mean Microvolt Amplitude by Class	*p* Value
1	F = - 9.3	*p* = 0.47
	UF = -11.0	
2	F = -11.1	*p* = 0.99
	UF = -11.1	
3	F = -12.8	*p* = 0.24
	UF = -10.0	
4	F = -14.3	*p* = 0.01*
	UF = - 9.6	
5	F = -13.3	*p* = 0.01*
	UF = - 8.2	

*Significant at the 0.05 level.

6.5.5 Results for the Slow Wave Component

The mean microvolt amplitudes by time, session and class for the three electrode channels are presented in appendix 6, tables 40, 41, and 42. No significant interaction effects were obtained for all three channels (tables 14, 15, and 16). At channel C4 and PZ significant main effects due to time were found (T1 was found to be of significantly greater negative amplitude than T2 for both these channels).

TABLE 14

RESULTS AND FOLLOW-UP ANALYSIS FROM A REPEATED MEASURES ANALYSIS OF VARIANCE PERFORMED ON THE MEAN AMPLITUDE OF THE SLOW WAVE EVOKED POTENTIAL COMPONENT RECORDED AT CHANNEL C3, N = 17

Main Effect	Mean Microvolt Amplitude	*p* Value
Session	= - 9.3	*p* = 0.51
Class	F = - 9.7	
	UF = - 8.9	
Time	T1 = -10.7	
	T2 = - 8.0	
Interaction Effect		
Session by Class		*p* = 0.26
Session by Time		*p* = 0.22
Class by Time		*p* = 0.48
Session by Class by Time		*p* = 0.85

*Significant at the 0.05 level.

TABLE 15

RESULTS AND FOLLOW-UP ANALYSIS FROM A REPEATED MEASURES ANALYSIS OF VARIANCE PERFORMED ON THE MEAN AMPLITUDE OF THE SLOW WAVE EVOKED POTENTIAL COMPONENT RECORDED AT CHANNEL C4, N = 17

Main Effect	Mean Microvolt Amplitude	p Value
Session	= -19.4	p = 0.62
Class	F = -19.8	p = 0.41
	UF = -19.0	
Time	T1 = -21.1	p = 0.02*
	T2 = -17.7	
Interaction Effect		
Session by Class		p = 0.08
Session by Time		p = 0.73
Class by Time		p = 0.71
Session by Class by Time		p = 0.91

*Significant at the 0.05 level.

TABLE 16

RESULTS AND FOLLOW-UP ANALYSIS FROM A REPEATED MEASURES ANALYSIS OF VARIANCE PERFORMED ON THE MEAN AMPLITUDE OF THE SLOW WAVE EVOKED POTENTIAL COMPONENT RECORDED AT CHANNEL PZ, N = 17

Main Effect	Mean Microvolt Amplitude	*p* Value
Session	= - 8.7	*p* = 0.87
Class	F = - 9.1	*p* = 0.46
	UF = - 8.2	
Time	T1 = -10.8	*p* = 0.002**
	T2 = - 6.5	
Interaction Effect		
Session by Class		*p* = 0.07
Session by Time		*p* = 0.47
Class by Time		*p* = 0.81
Session by Class by Time		*p* = 0.46

**Significant at the 0.005 level.

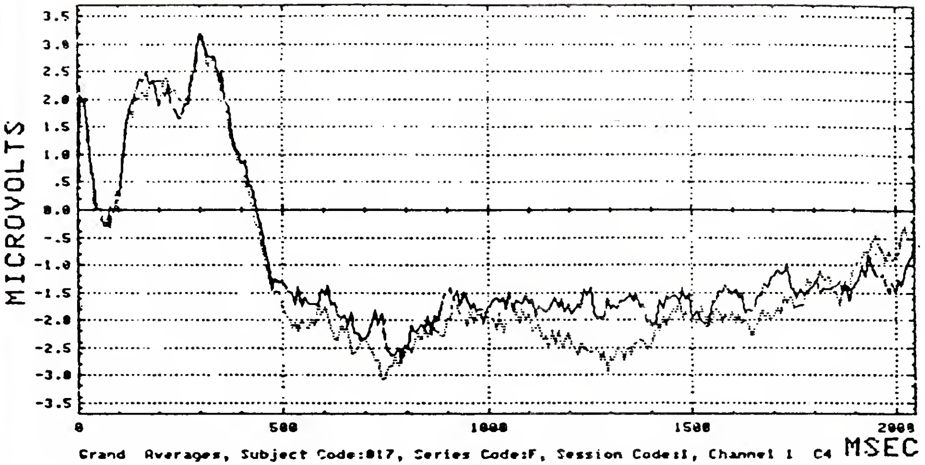

Figure 1. EPR by Class: Time = 1, Session 1, Channel = C4.

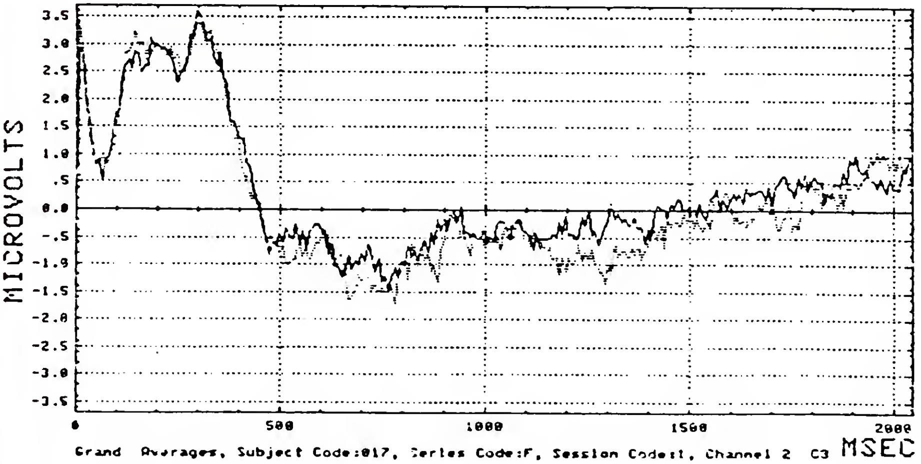

Figure 2. EPR by Class: Time = 1, Session 1, Channel = C3.

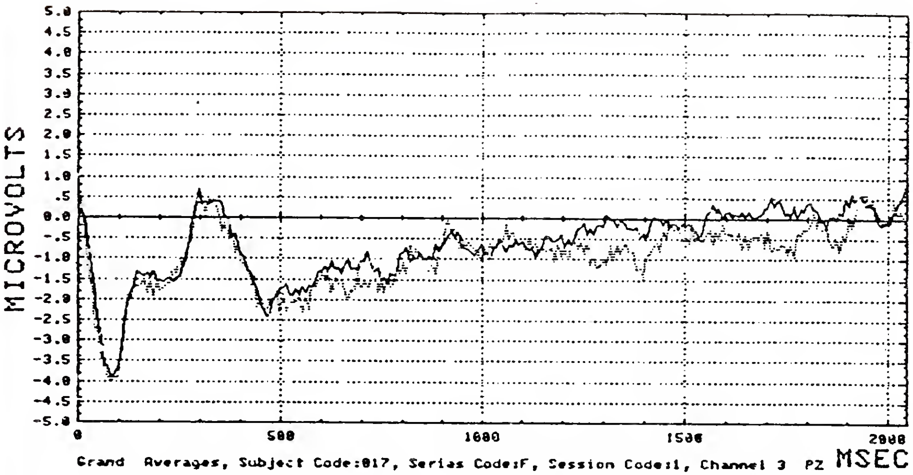

Figure 3. Evoked Response by Class Averaged Across Subjects (N = 17): Time = 1, Session = 1, Channel = PZ.

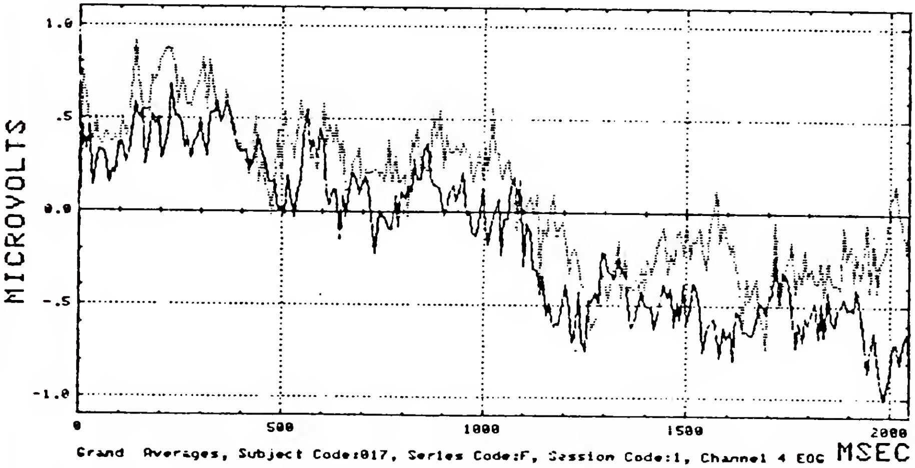

Figure 4. Evoked Response by Class Averaged Across Subjects (N = 17): Time = 1, Session = 1, Channel = EOG.

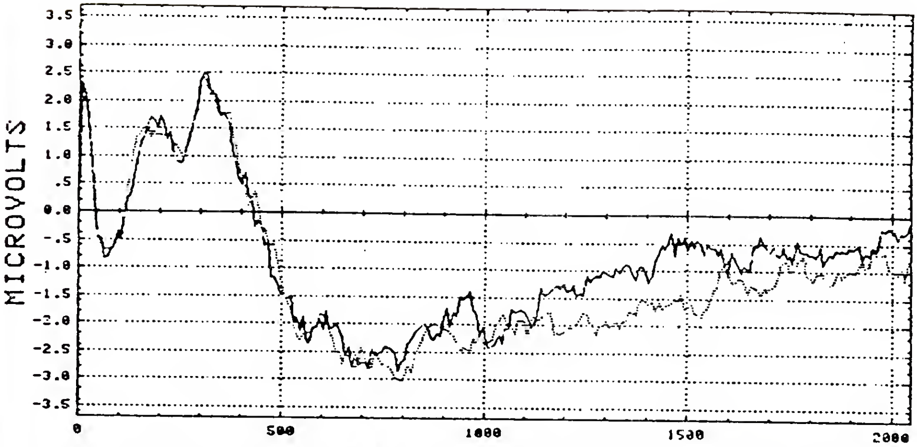

Figure 5. Evoked Response by Class Averaged Across Subjects (N = 17): Time = 1, Session = 2, Channel = C4.

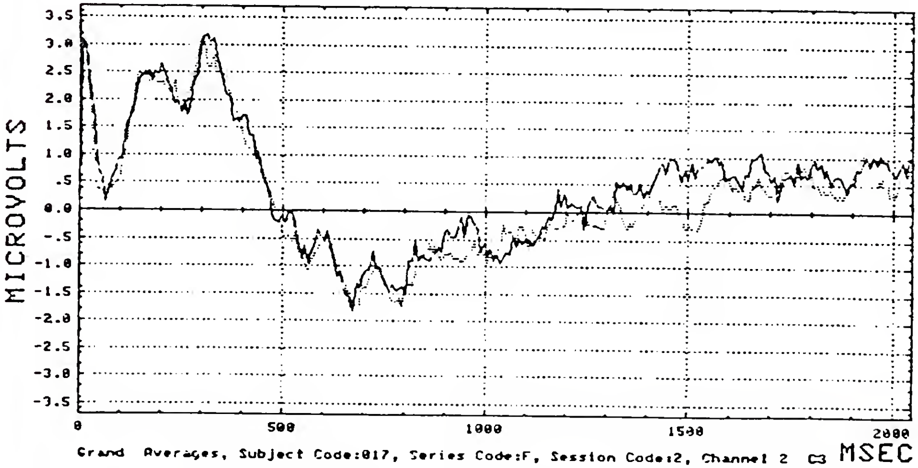

Figure 6. Evoked Response by Class Averaged Across Subjects (N = 17): Time = 1, Session = 2, Channel = C3.

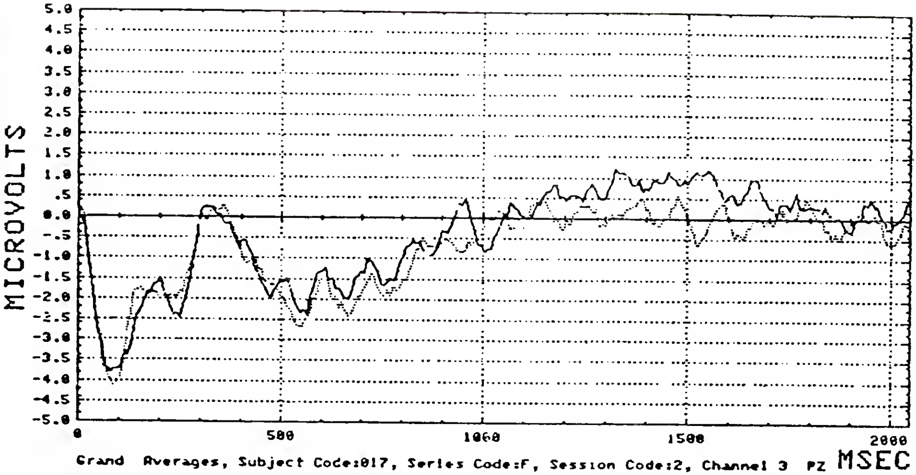

Figure 7. Evoked Response by Class Averaged Across Subjects (N = 17): Time = 1, Session = 2, Channel = PZ.

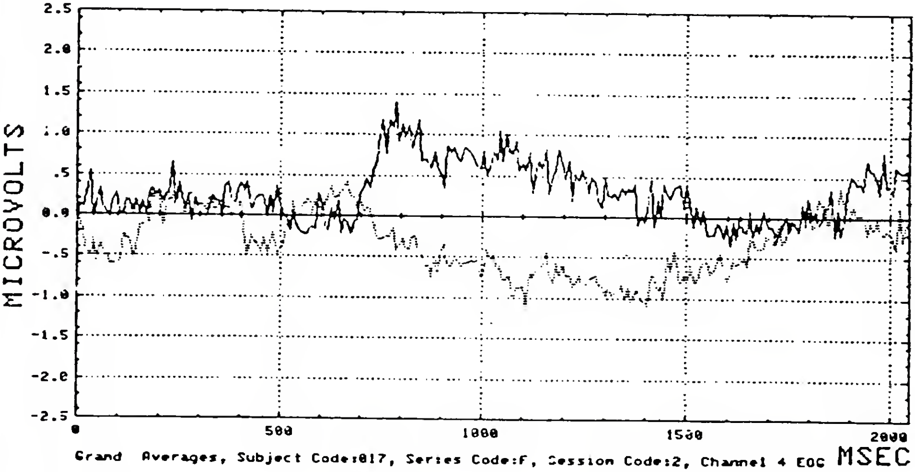

Figure 8. Evoked Response by Class Averaged Across Subjects (N = 17): Time = 1, Session = 2, Channel = EOG.

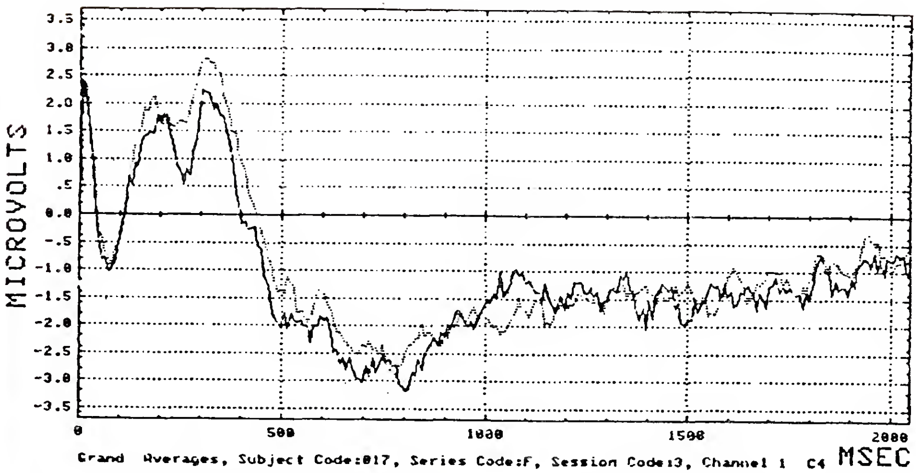

Figure 9. Evoked Response by Class Averaged Across Subjects (N = 17): Time = 1, Session = 3, Channel = C4.

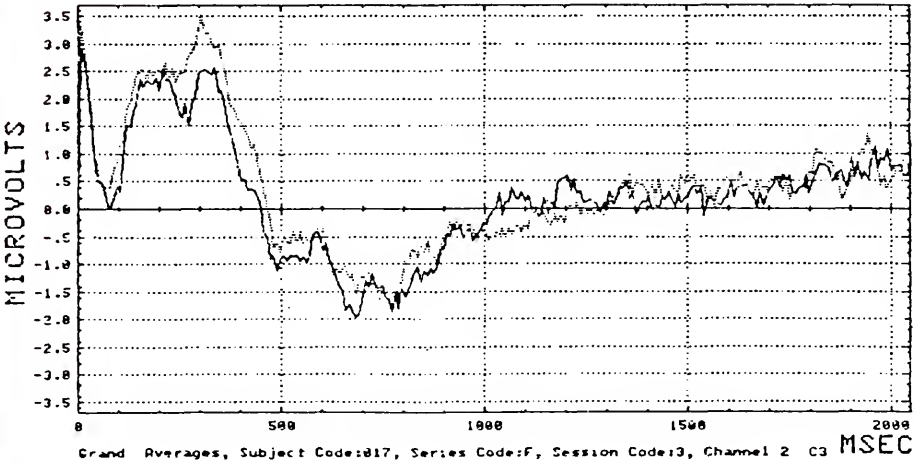

Figure 10. Evoked Resonse by Class Averaged Across Subjects (N = 17): Time = 1, Session = 3, Channel = C3.

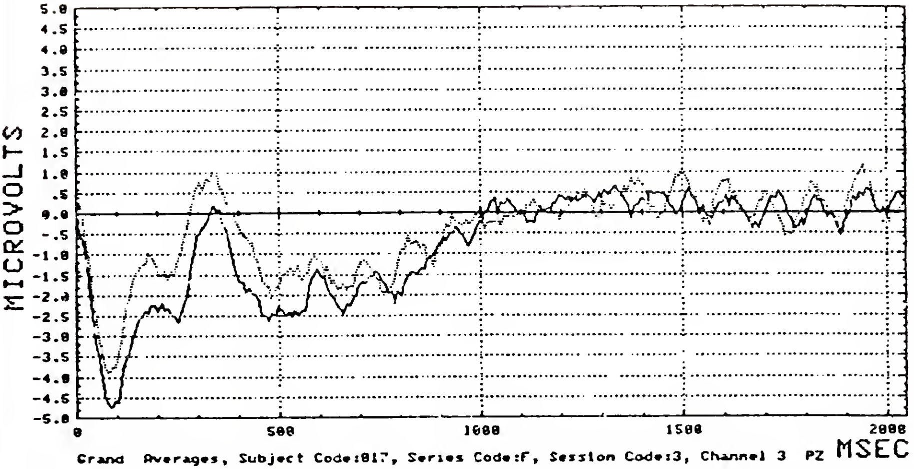

Figure 11. Evoked Response by Class Averaged Across Subjects (N = 17): Time = 1, Session = 3, Channel = PZ.

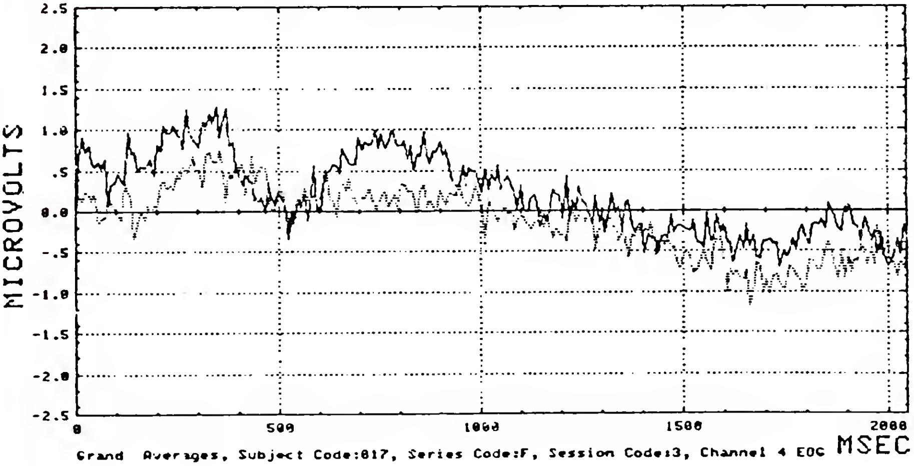

Figure 12. Evoked Response by Class Averaged Across Subjects (N = 17): Time = 1, Session = 3, Channel = EOG.

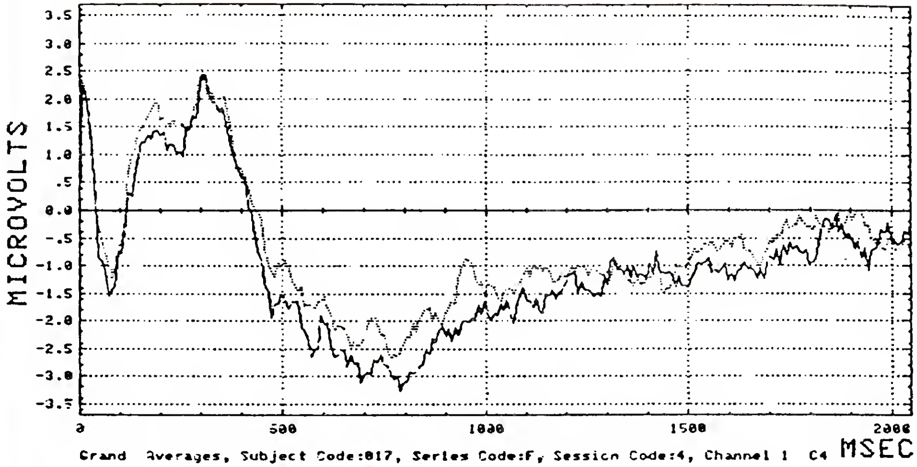

Figure 13. Evoked Response by Class Averaged Across Subjects (N = 17): Time = 1, Session = 4, Channel = C4.

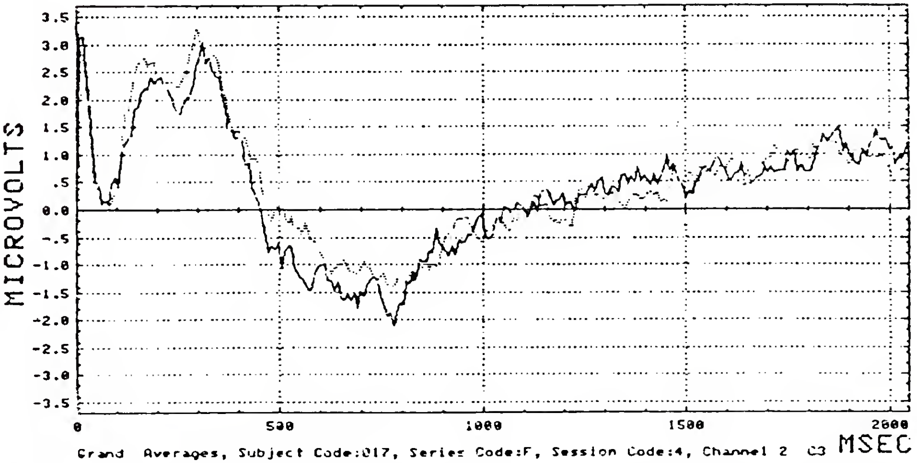

Figure 14. Evoked Response by Class Averaged Across Subjects (N = 17): Time = 1, Session = 4, Channel = C3.

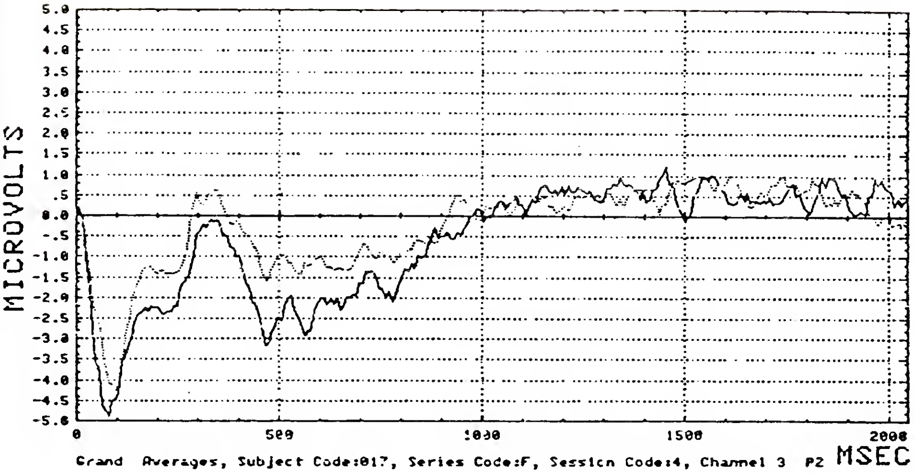

Figure 15. Evoked Response by Class Averaged Across Subjects (N = 17): Time = 1, Session = 4, Channel = PZ.

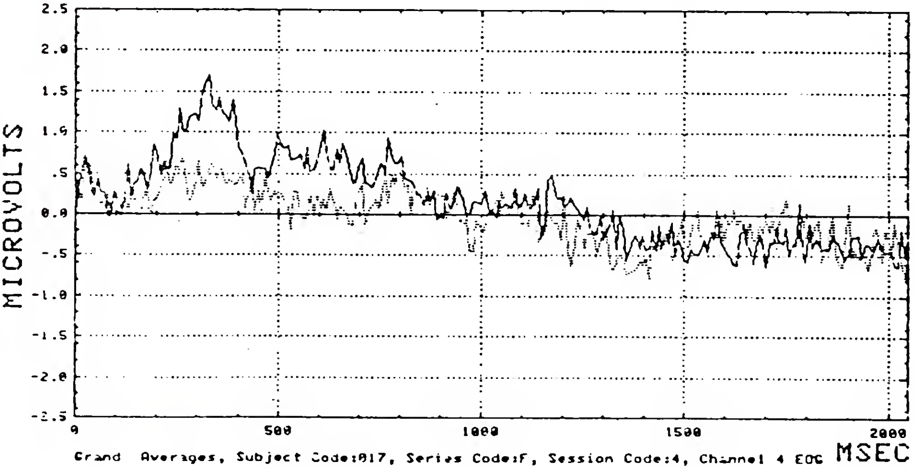

Figure 16. Evoked Response by Class Averaged Across Subjects (N = 17): Time = 1, Session = 4, Channel = EOG.

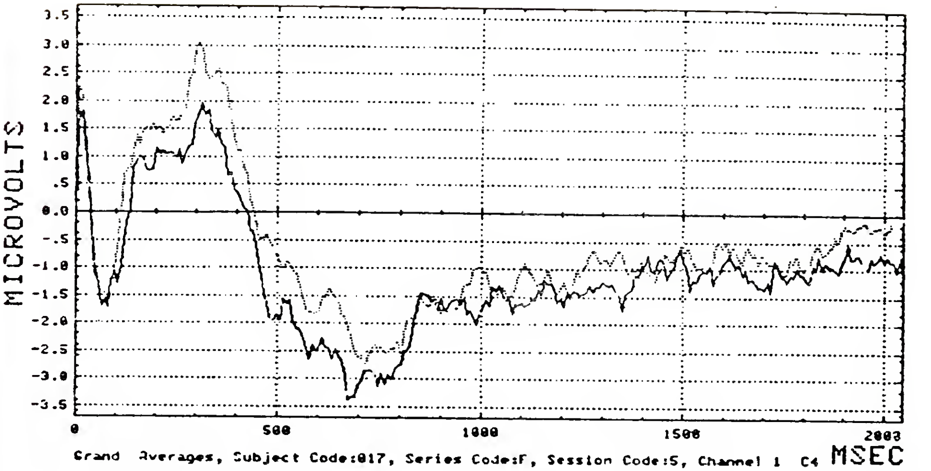

Figure 17. Evoked Response by Class Averaged Across Subjects (N = 17): Time = 1, Session = 5, Channel = C4.

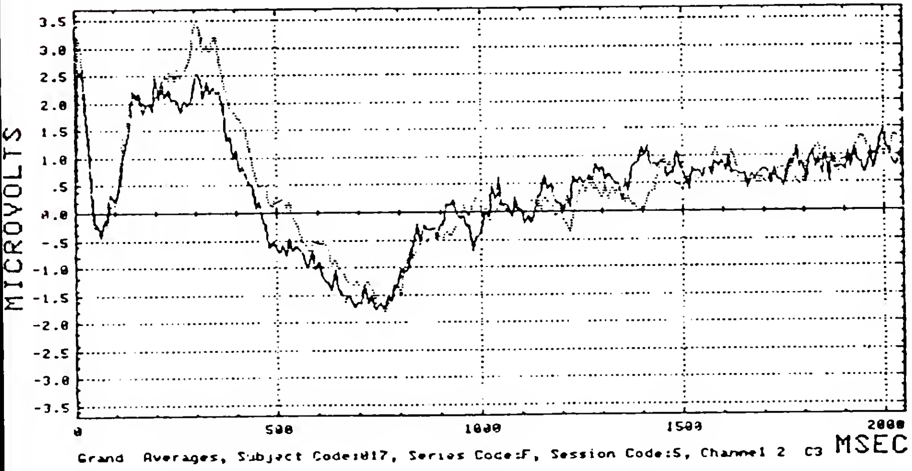

Figure 18. Evoked Response by Class Averaged Across Subjects (N = 17): Time = 1, Session = 5, Channel = C3.

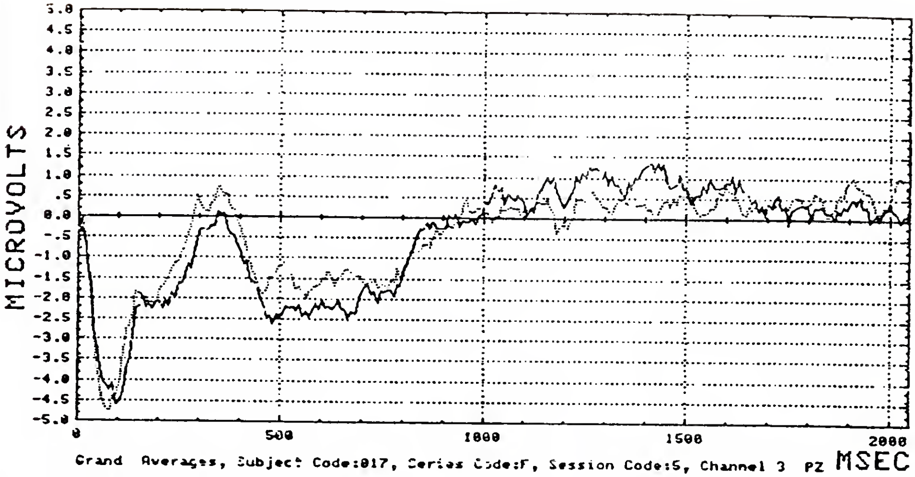

Figure 19. Evoked Response by Class Averaged Across Subjects (N = 17): Time = 1, Session = 5, Channel = PZ.

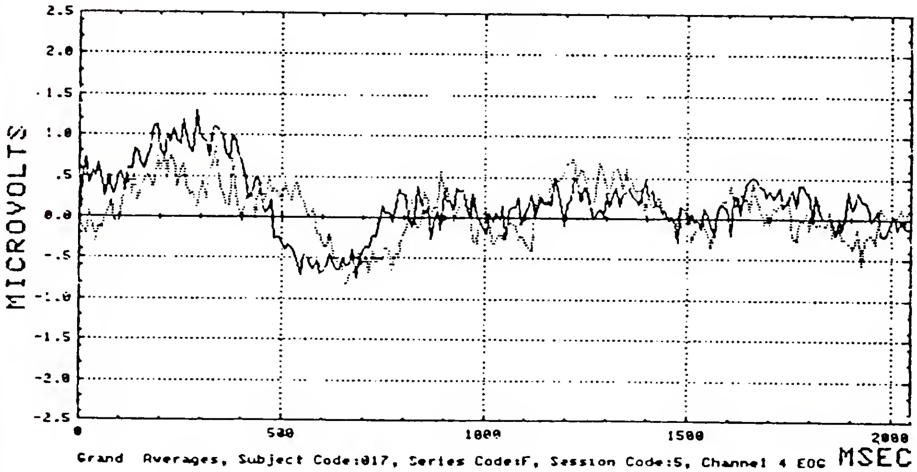

Figure 20. Evoked Response by Class Averaged Across Subjects (N = 17): Time = 1, Session = 5, Channel = EOG.

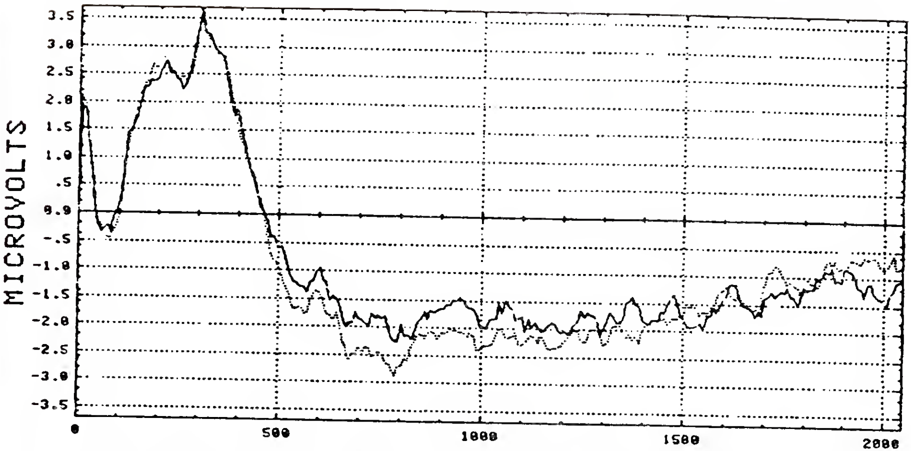

Figure 21. Evoked Response by Class Averaged Across Subjects (N = 17): Time = 2, Session = 1, Channel = C4.

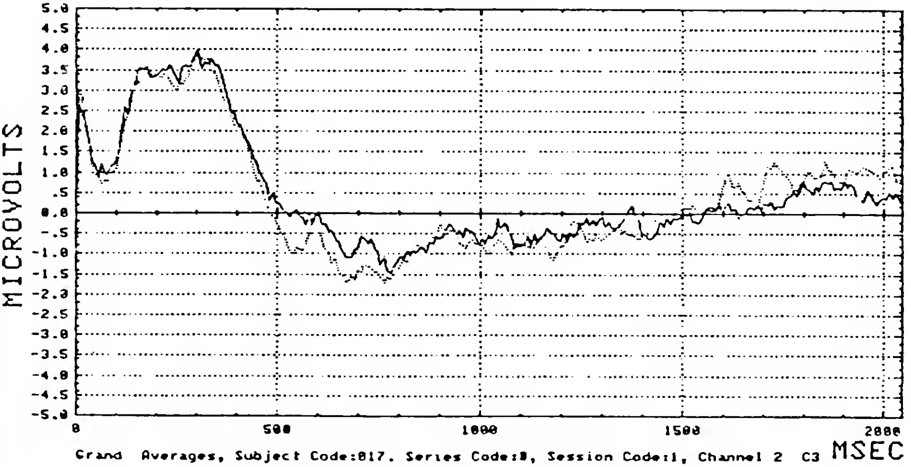

Figure 22. Evoked Response by Class Averaged Across Subjects (N = 17): Time = 2, Session = 1, Channel = C3.

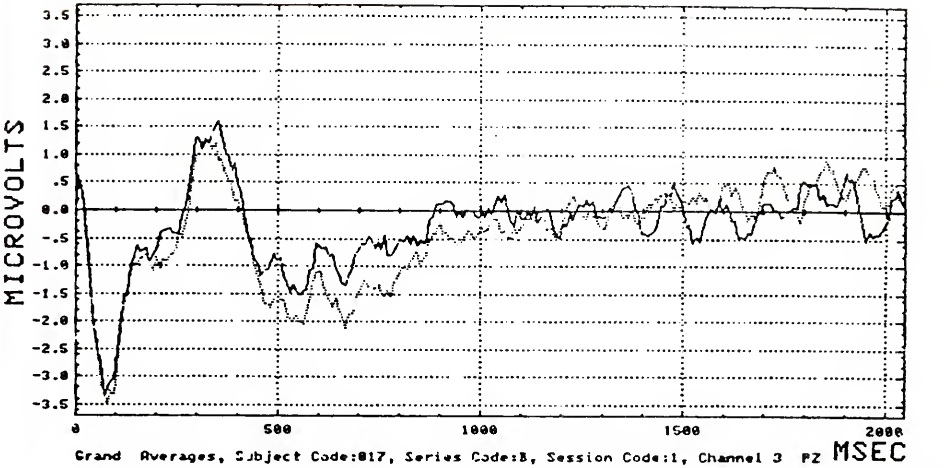

Figure 23. Evoked Response by Class Averaged Across Subjects (N = 17): Time = 2, Session = 1, Channel = PZ.

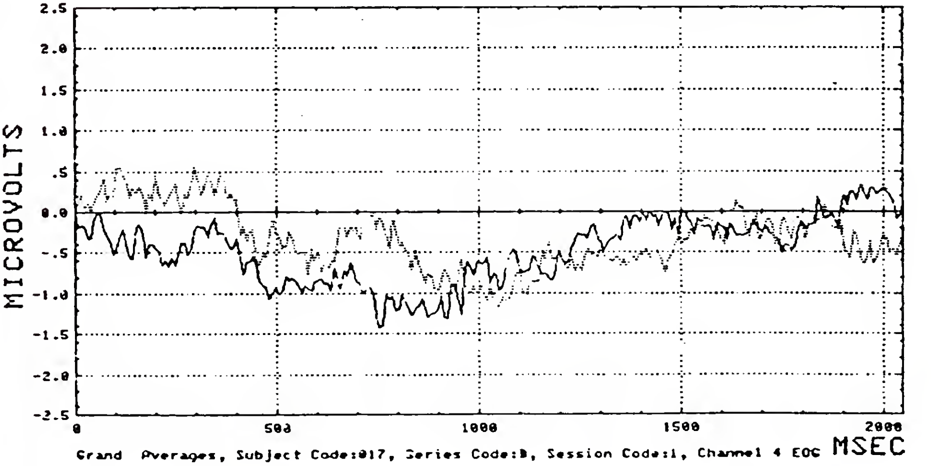

Figure 24. Evoked Response by Class Averaged Across Subjects (N = 17): Time = 2, Session = 1, Channel = EOG.

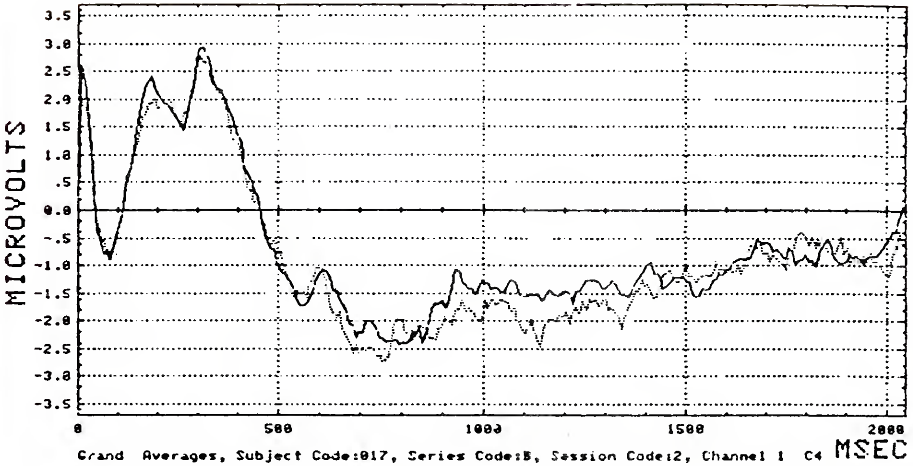

Figure 25. Evoked Response by Class Averaged Across Subjects (N = 17): Time = 2, Session = 2, Channel = C4.

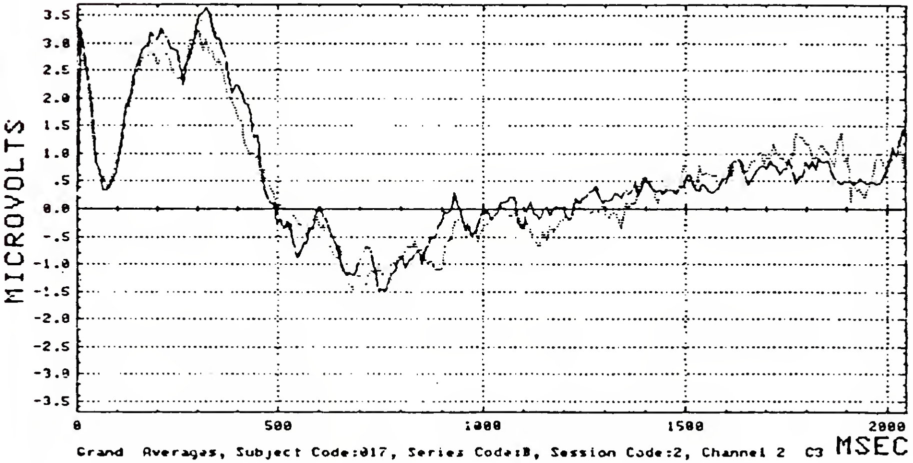

Figure 26. Evoked Response by Class Averaged Across Subjects (N = 17): Time = 2, Session = 2, Channel = C3.

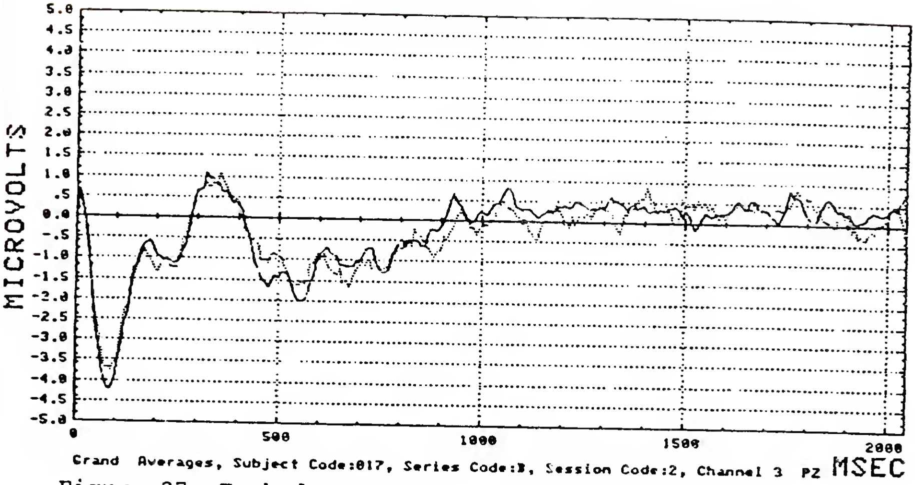

Figure 27. Evoked Response by Class Averaged Across Subjects (N = 17): Time = 2, Session = 2, Channel = PZ.

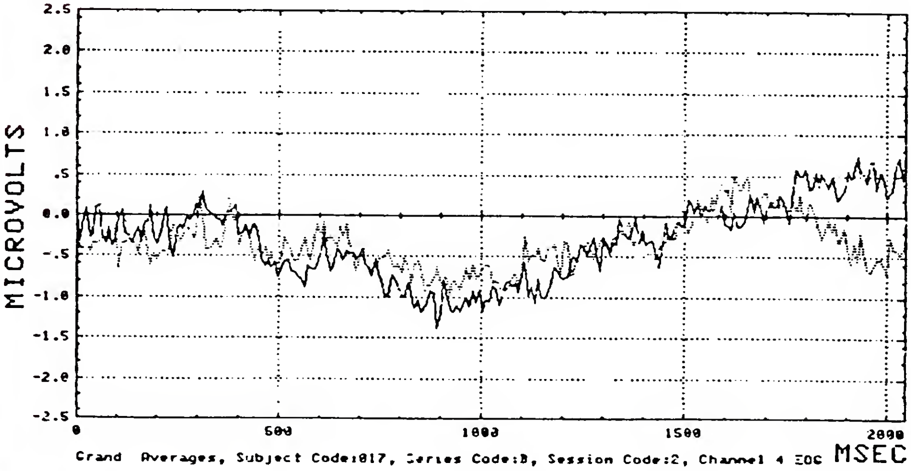

Figure 28. Evoked Response by Class Averaged Across Subjects (N = 17): Time = 2, Session = 2, Channel = EOG.

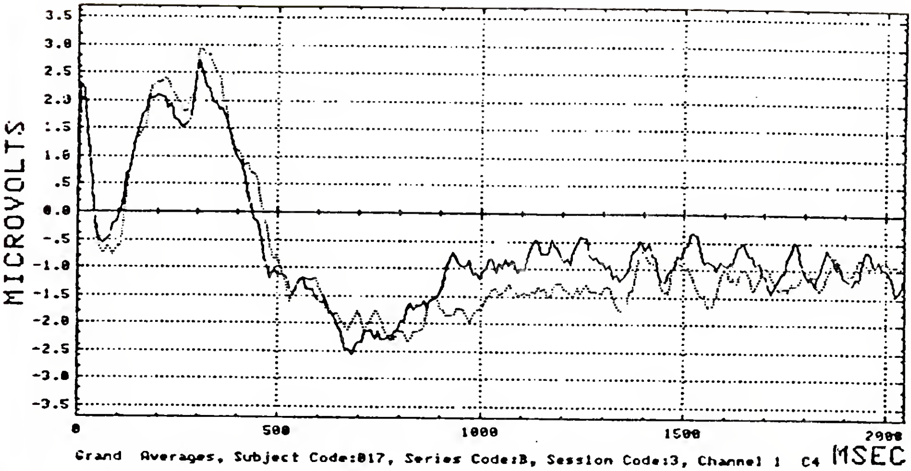

Figure 29. Evoked Response by Class Averaged Across Subjects (N = 17): Time = 2, Session = 3, Channel = C4.

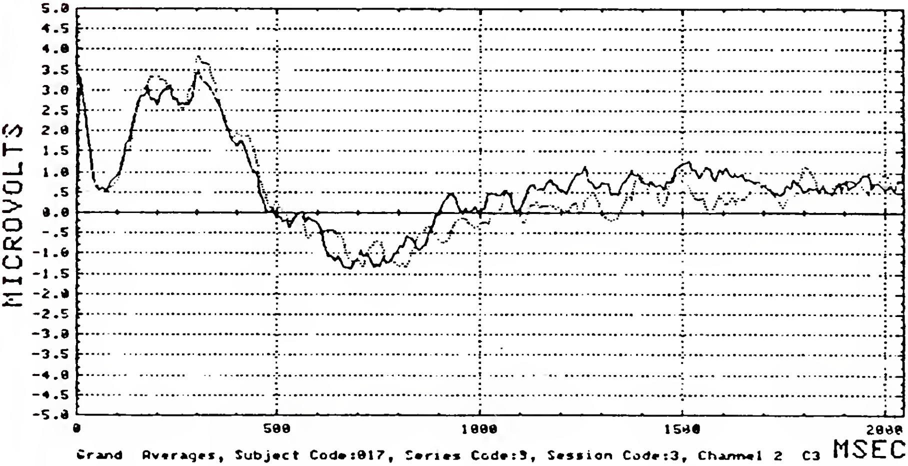

Figure 30. Evoked Response by Class Averaged Across Subjects (N = 17): Time = 2, Session = 3, Channel = C3.

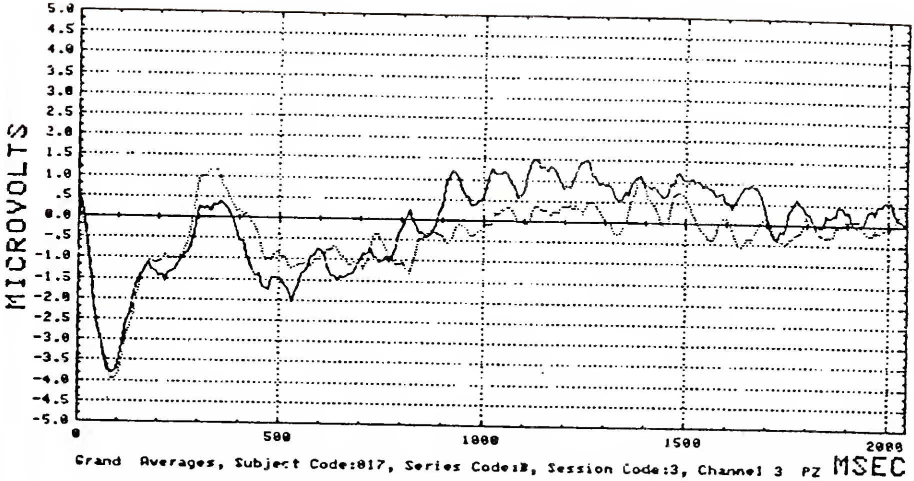

Figure 31. Evoked Response by Class Averaged Across Subjects (N = 17): Time = 2, Session = 3, Channel = PZ.

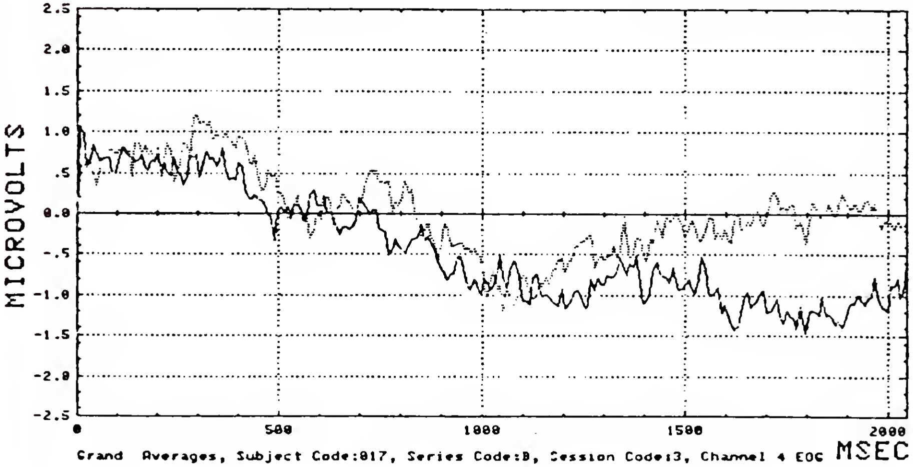

Figure 32. Evoked Response by Class Averaged Across Subjects (N = 17): Time = 2, Session = 3, Channel = EOG.

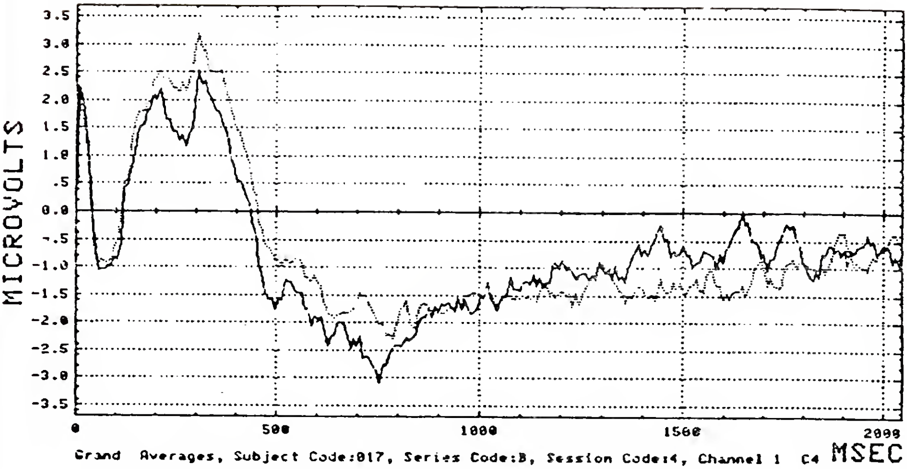

Figure 33. Evoked Response by Class Averaged Across Subjects (N = 17): Time = 2, Session = 4, Channel = C4.

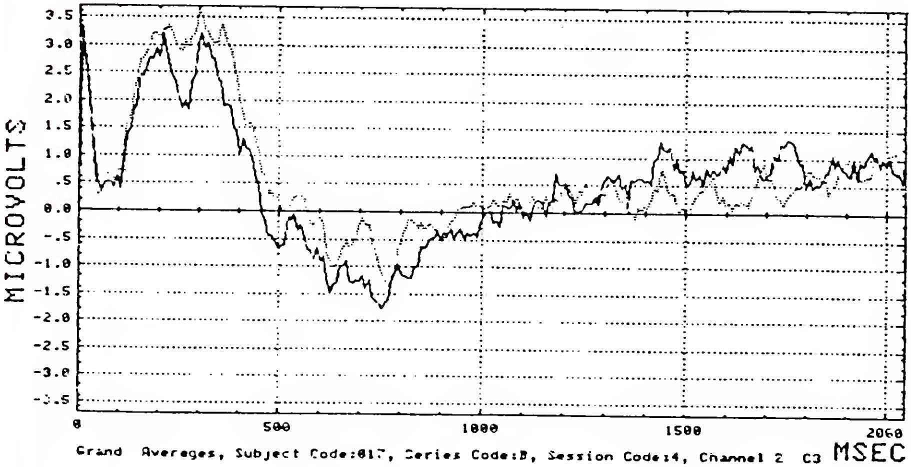

Figure 34. Evoked Response by Class Averaged Across Subjects (N = 17): Time = 2, Session = 4, Channel = C3.

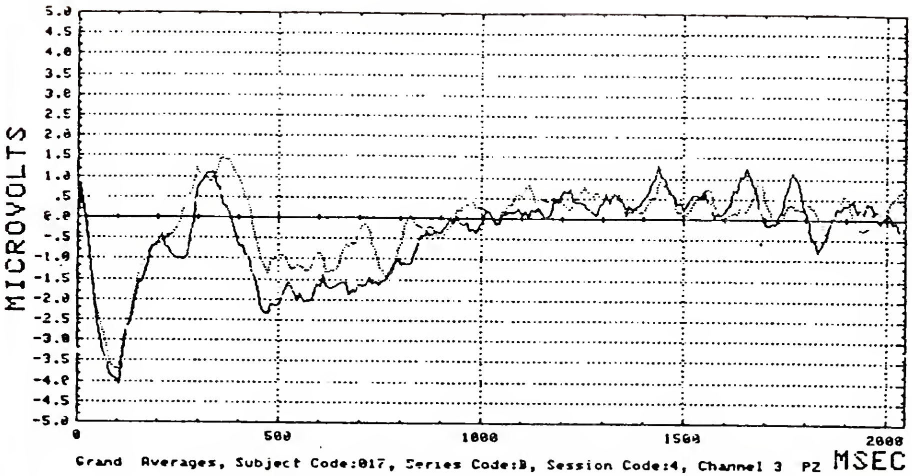

Figure 35. Evoked Response by Class Averaged Across Subjects (N = 17): Time = 2, Session = 4, Channel = PZ.

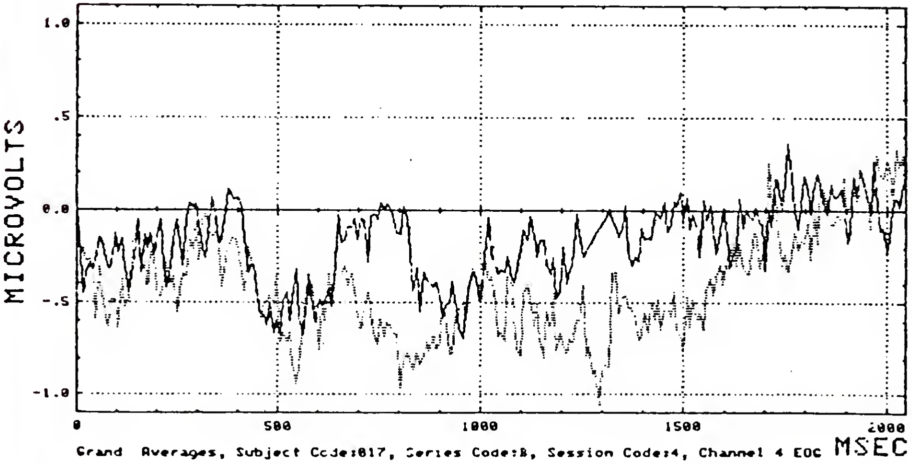

Figure 36. Evoked Response by Class Averaged Across Subjects (N = 17): Time = 2, Session = 4, Channel = EOG.

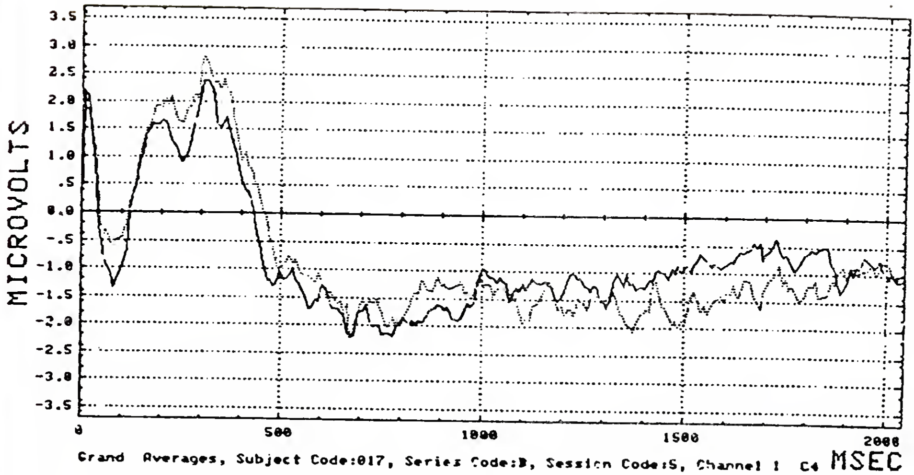

Figure 37. Evoked Response by Class Averaged Across Subjects (N = 17): Time = 2, Session = 5, Channel = C4.

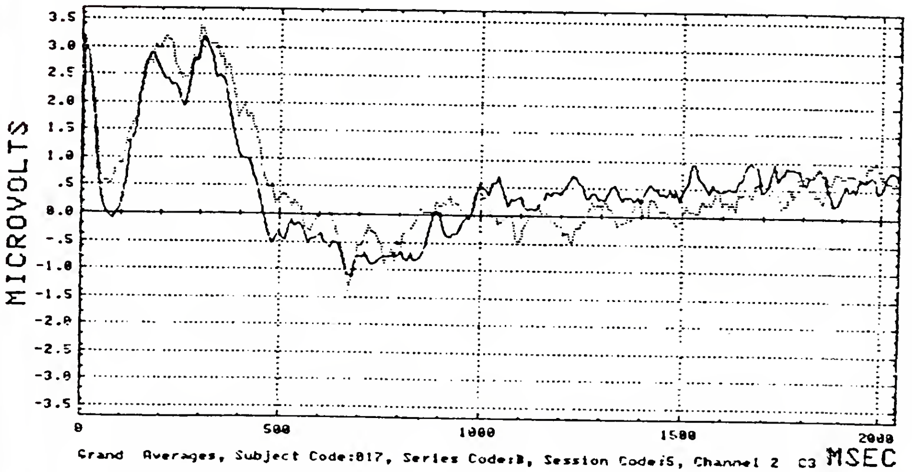

Figure 38. Evoked Response by Class Averaged Across Subjects (N = 17): Time = 2, Session = 5, Channel = C3.

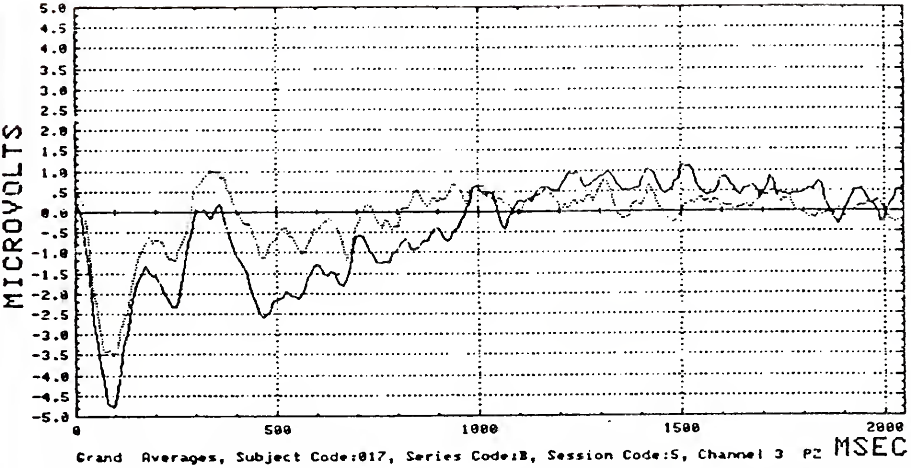

Figure 39. Evoked Response by Class Averaged Across Subjects (N = 17): Time = 2, Session = 5, Channel = PZ.

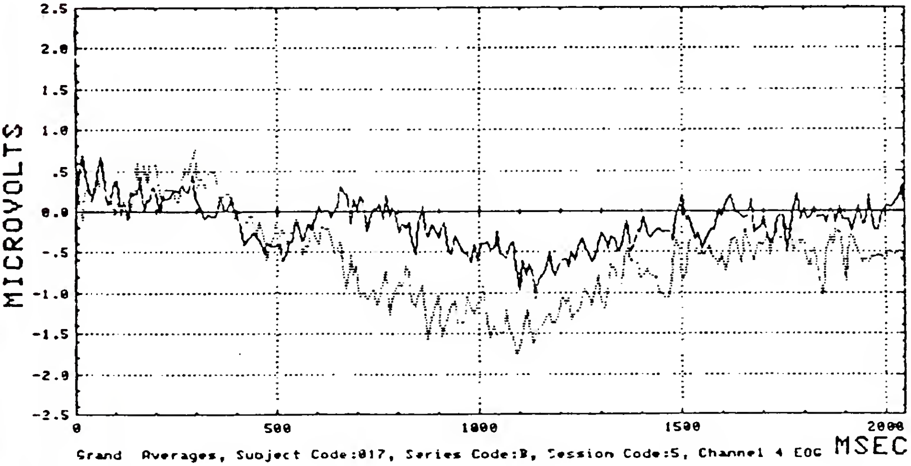

Figure 40. Evoked Response by Class Averaged Across Subjects (N = 17): Time = 2, Session = 5, Channel = EOG.

6.6 Plots of Averaged Evoked Potentials

The ERP averaged across subjects (N=17) for the two classes of stimuli, familiar (represented by the solid line) and unfamiliar (represented by the dotted line) by session (Code: 1-5), channel (channel: 1 = C4, 2 = C3, 3 = PZ, 4 = EOG) and time (time 1 = series code: F; time 2 = series code: B) are plotted in Figures 1-40. In Figure 1 the N100, P300, P400, negative and slow wave evoked potential components are indicated.

In examining the figures, two considerations were necessary. First electrode channels (C3, C4, PZ) were not calibrated to one another, and as such comparison of one channel to another was inappropriate; and secondly, values on the microvolt and millisecond axis were relative and not absolute.

It should be noted that the EOG channel (channel 4) was used solely to detect eye movement artifact (blinks, etc.).

CHAPTER VII
DISCUSSION

7.1 Variability Due to Experimenter Error, A Caveat

Two sources of variability, which potentially could have affected the obtained results, were discovered upon the completion of the present study. One source of variability was associated with the sequencing of EEG collection and the onset of the stimulus. The second source of variability was related to the discriminability of the two classes of slides (familiar, unfamiliar).

In collection of the EEG it is optimal to begin the collection with the onset of the stimulus. Collecting the EEG either before or after the onset of the stimulus would result in shifting the evoked response on the abscissa (millisecond axis). If the error in sequencing was constant, the averaged evoked response would be shifted by that constant, and the integrity of the evoked response configuration would be maintained. For example, if EEG collection began 100 milliseconds after stimulus onset, the subsequent averaged evoked response would reveal the P300 component to be at 200 rather than 300 milliseconds. However, should the error in sequencing be random, the configuration of the evoked response, particularly early components, would be greatly affected.

In the present experiment the actual collection of EEG was 250 milliseconds after the pulse sent to advance the slide tray. The rationale behind the 250 millisecond lapse was that it took approximately that amount of time for the projector after having received the five-volt pulse to advance and present the slide to the subject. While the 250-millisecond lapse could induce some sequencing slippage between the collection of EEG and stimulus onset, the time differential would be constant, small (perhaps ± 10 milliseconds), and therefore negligible. A more serious problem would be if the slides themselves varied in the time they took to drop from the tray into the loaded position. While this particular circumstance was not controlled for, the results from any actual variability could be inferred from the data.

In examining peak amplitude of the N100 component (Chapter VI, 6.4.1) averaged across subjects (Figures 1-40), it was observed that the latency of this component was consistent by class, session, electrode position and time (typically 80 milliseconds). Furthermore, the configuration of the N100 component in the present study was consistent with N100 components typically reported in the literature. Therefore, as the N100 component is affected by the physical qualities of the stimulus which were controlled for (Chapter II, 2.1), variability in the latency of this component would be the result of variability in the latency of stimulus onset. The observed latency of the N100 component in the present study was minimal, with a consistent configuration by class, session, electrode position and time. It was concluded, therefore, that uncontrolled variability in the sequencing of EEG collection to the stimulus onset was constant and minimal. The impact of this potential artifact upon the obtained results was determined not to be significant. It is recommended, however, that future experimentation be conducted with appreciation and, where necessary, control for this potential artifact.

A second potential source of uncontrolled variability was suggested from the results of a follow-up experiment conducted after the completion of the present study. An unpublished pilot study was conducted in 1982 by D. Haymaker at the Vision Laboratory, University of Florida, Department of Clinical Psychology. In that study subjects' (N = 4) ability to discriminate the familiar and unfamiliar slides used in the present study was tested. Subjects were presented once with the slides from sessions 1-5, with a stimulus duration of one second (as opposed to 400 milliseconds used in the present study). The task was to rate each slide (immediately after presentation) as familiar or unfamiliar. In sessions 3, 4 and 5, 90%, 95% and 92% (respectively) of the familiar slides, however, from sessions 3, 4 and 5, only 55%, 70% and 75% (respectively) were judged correctly. Subjects' ability to correctly identify familiar slides as familiar (90% or better) was consistent with the levels of excellence reported by earlier researchers (see Chapter I, 1.2). Subjects' performance with the unfamiliar slides indicates that 45% of the unfamiliar slides from session 3, 30% from session 4 and 25% from session 5 were incorrectly judged to be familiar. While this level of performance was not predicted from earlier reports in the literature, it was consistent with more recent studies examining recognition memory for pictures. Goldstein et al. (1982) examined dynamic (video tape) vs. static stimuli (slides), and differences in recognition memory. In their static-static condition their subjects studied 60 video freeze frames (slides) for approximately five seconds (vs. one second in the pilot study and 400 milliseconds in the present study). Recognition testing consisted of 120 freeze frames, 30 targets and 90 foils. Subjects' performance was similarly found not to approach the levels of excellence reported by earlier researchers. In the Goldstein study approximately 15% of the unfamiliar slides were incorrectly judged familiar (vs. a 25% false alarm rate found in the pilot study at session 5).

The findings from the Goldstein study, and the suggestions from the pilot study, have important implications for further research. While subjects' ability to discriminate familiar from unfamiliar complex pictorial stimuli remained high in the two studies (and consistent with previous findings), subjects' ability to discriminate unfamiliar from familiar stimuli was suggested to be different, and of lesser accuracy. Further experimentation examining the interaction between task difficulty (stimulus exposure time, complexity and discriminability), hit and false alarm rates in a recognition paradigm is indicated.

Of particular concern to the present study was the effect of unfamiliar slides viewed as familiar upon the obtained results. Increasing the difficulty to discriminate the two classes of stimuli (probability due to the similarity between classes, as all slides were landscape scenes; or task difficulty imposed by a 400 msec stimulus duration) would be predicted to increase the difficulty of discriminating between the two classes in subsequent analysis of performance measures. Increased difficulty in discrimination would be expected to bias subsequent analysis of the evoked response towards non-significance. This would occur because decreased difference in responses to the two classes of stimuli due to artifact (i.e. similarity between some familiar and unfamiliar slides).

7.2 Discussion of the Results and Hypothesis

7.2.1 Discussion of the P300 Results and Hypothesis

It was predicted that in comparison with the response to unfamiliar stimuli, the P300 response to the familiar class of stimuli would decrease with increased repetition (familiarity). Examination of the evoked response averaged across subjects (Figures 1-40) supported this prediction. No appreciable difference was observed in the P300 component between the two classes of stimuli (familiar = solid line, unfamiliar = dotted line) in the first two sessions for channels C4, C3 and PZ (time one, Figures 1, 2, 3, 5, 6, and 7; time two, Figures 21, 22, 23, 25, 26, and 27). This was expected since in sessions 1 and 2 the same slides were presented. In sessions 3, 4, and 5 a decrease in P300 amplitude for the familiar stimuli was expected and observed in channels C3, C4 and PZ, for both time one and time two (time one, session 3, Figures 9, 10, and 11; session 4, Figures 13, 14, and 15; session 5, Figures 17, 18, and 19; time two, session 3, Figures 29, 30, and 31; session 4, Figures 33, 34, and 35; session 5, Figures 37, 38, and 39). The results from the repeated measures analysis of variance were also consistent with the predicted changes. Of particular importance were the session by class interactions.

For each of the three channels (C3, C4, PZ) no significant differences were obtained between the mean P300 response for the two classes of stimuli (familiar and unfamiliar) for sessions 1 and 2, at time one and time 2 (session by class interaction, tables 5, 6, 7). As already discussed, this was to be expected since the slides presented in session 1 were presented in session 2. The amplitude of the mean P300 component to the familiar class of stimuli was found to be significantly less than the amplitude of the P300 component to the unfamiliar stimuli for the three channels at sessions 3, 4 and 5, at time one and time two (tables 8, 9, 10) with one exception.

At channel PZ, session 4, no significant difference between the two classes of stimuli was obtained, however, a trend in the predicted direction was observed (and was significant at the 0.12 level, table 7). These patterns of obtained results for the P300 component between the two classes of stimuli at session 3, 4, and 5 were predicted to occur.

Based on the significant results obtained for the mean P300 component from the repeated measures analysis of variance (tables 5, 6, and 7), which were supported by the plots of the averaged evoked response (figures 1-40), the nul hypothesis was rejected. It was concluded that the mean P300 response did not differ significantly at sessions 1 and 2, for both times, at channels C3, C4 and PZ. Furthermore, it was concluded that the mean P300 response to the familiar class of stimuli was of significantly less amplitude than the mean P300 response to the unfamiliar stimuli for sessions 3, 4 and 5, at both time one and time two.

7.2.2 Discussion of the P400 Results and Hypothesis

Similar to the P300 hypothesis, the P400 component was predicted to decrease in amplitude with increasing familiarity. It was expected that no difference between

P400 components elicited by the two classes of stimuli would occur for sessions 1 and 2. For sessions 3, 4 and 5 the P400 component elicited by the familiar stimuli was expected to be of less amplitude than the P400 component elicited by the unfamiliar class of stimuli. The plots of the averaged evoked response (Figures 1-40), and the results obtained from the repeated measures analysis of variance were consistent with the predictions for the P400 component.

Similar to the P300 component, and as expected, no appreciable difference was observed in the P400 component between the two classes of stimuli in the first two sessions, for channels C4, C3 and PZ, at time one and time two (time one, Figures 1, 2, 3, 5, 6, and 7; time two, Figures 21, 11, 23, 15, 26, 27). Differences were observed in sessions 3, 4, and 5, both at time one and time two (time one, Figures 9, 10, 11, 13, 14, 15, 17, 18, and 19; time two, Figures 29, 30, 31, 33, 34, 35, 37, 38, and 39). As predicted, the P400 component elicited by the familiar class of stimuli was observed in the above figures to be of less amplitude than the P400 component elicited by the unfamiliar stimuli. Results from the repeated predictions made in the P400 hypothesis.

For channels C3, C4, and PZ, time one and time two, no significant differences were obtained between the mean P400 responses for the two classes of stimuli at sessions 1, 2 and 3 (session by class interaction, tables 8, 9, and 10).

The amplitude of the P400 component to the familiar class of stimuli was significantly less than the amplitude of the P400 component to the unfamiliar class of stimuli for sessions 4 and 5, at both time one and time two, for all three electrode channels (tables 8, 9, 10), with one exception. No significant difference between the two classes of stimuli was observed at channel C4, session 5. A trend in the predicted direction, however, was observed (the P400 amplitude to the familiar class of stimuli was less than the P400 amplitude to the unfamiliar class of stimuli and was significant at he 0.1 level).

Based upon the results obtained from the repeated measures analysis of variance performed on the P400 component, and from visual inspection of the evoked response averaged across subjects (Figures 1-40), the null hypothesis was rejected. It was concluded that the P400 response did not differ by class of stimuli in sessions 1, 2 and 3. Furthermore, it was concluded that with increased familiarity (sessions 4 and 5) the P400 component elicited by the familiar P400 component elicited by the unfamiliar stimuli.

7.2.3 Discussion of the Slow Wave Results and Hypothesis

The slow wave evoked potential component was also hypothesized to show a decrease in amplitude with increased familiarity. Specifically, no class difference was expected in sessions 1 and 2. In sessions 3, 4 and 5 the slow wave component elicited from the familiar class of stimuli was expected to be of less amplitude than the slow wave elicited from the unfamiliar stimuli.

No significant interaction effects were obtained, however, from the repeated measures analysis of variance for any of the three channels (tables 14, 15 and 16). This pattern of results was not predicted to occur. Based upon the findings that the mean slow wave component to the familiar stimuli did not decrease with increased familiarity, the null hypothesis was not rejected. It was concluded that the mean slow wave amplitude did not differ by class (familiar and unfamiliar) across the 5 experimental sessions, at both time one and time two, for channels C4, C3, and PZ.

7.3 Summary and Conclusions for the P300, P400 and Slow Wave Hypotheses

The results obtained from analysis of the P300 and P400 components were consistent with predictions made in the hypotheses, and support two of the three suggestions put forth by Kok and Looren de Jong (1980; see Chapter III, 3.2). These authors proposed that the P300, P400 and slow wave evoked potential components were related to two stages of information processing, preliminary categorization and continued processing. Changes in P300 were seen as a manifestation of the preliminary stage of stimulus categorization. The P400 component was seen as a demand or all for continued processing. An the slow wave was interpreted as reflecting the allocation of mental effort for the rehearsal of perceptual stimulus characteristics in short-term memory.

Since the results from the present study confirm some but not all of the initial hypotheses, they cannot be interpreted as clear support for the orienting response interpretation put forth by Kok and Looren de Jong (1980). Clear conclusions were drawn, however, for the more fundamental question of habituation.

Recall from previous discussion (Chapter III, 3.2), Kok and Looren de Jong (1980) concluded that the significant results in their study were not attributable to a general decrease in arousal or habituation. The procedures they used to obtain evoked potential averages for their classes of stimuli, however, were based on three different stimulus frequencies. Therefore, habituation could explain the observed decrease in amplitude of the evoked response to the familiar class of stimuli.

7.4 Habituation, Something Old, Something New

The effects of habituation upon the evoked response is an important concern to researchers (see Appendix 6). The fundamental task in working with the later endogenous evoked potentials, such as P300 and P400, is to be able to conclude that the experimental variability is the result of cognitive processes (such as memory), and not the result of general habituation (habituation other than stimulus quality habituation, Appendix 6, II, D). Three lines of evidence, the N100, negative and slow wave evoked potential components were used to argue that in the present study, the decreased amplitude of the evoked response to the familiar class of stimuli was the result of memory processes and not the result of general habituation.

7.4.1 The N100 Component

In the present study factors which contribute to slow and fast habituation were controlled for (see Appendix 6). The effectiveness of these controls, particularly for fast habituation, can be inferred from the results obtained from the analysis of the N100 component.

Gaillard (1976) demonstrated that random vs. constant inter-stimulus intervals results in no response decrement in the amplitude of the N100 component. In the present study random inter-stimulus intervals were used. Results of the repeated measures analysis of variance for channels C3, C4 and PZ (Tables 2, 3, 4) indicate that no significant class differences were obtained for the N100 component across all five sessions, for both time one and time two. Visual inspection of Figures 1-40 was consistent with this finding.

It can be concluded from these findings that the class differences observed in the P300, P400 and negative components were not due to physical differences between the two classes of stimuli (familiar and unfamiliar), or due to arousal level. The N100 is an exogenous evoked potential (Chapter II, 2.2), and is sensitive to the physical characteristics of the stimuli and the subjects' arousal level. The N100 component is not interpreted in the literature as being sensitive to cognitive processes, such as memory. And as there were no class differences in the N100 response in the present study, these factors could not explain the class difference observed in the P300, P400, and negative components.

7.4.2 The Slow Wave Component

It could possibly be argued that habituation differentially affects exogenous and endogenous evoked potential components, though no such argument has been addressed in the literature. To argue against this hypothesis in the present study it would be necessary to demonstrate that at least one of the later endogenous components did not differ by class. Such a finding was demonstrated. No significant session by class interaction was observed in any of the three electrode channels, at both time one and time two for the slow wave component (tables 14, 15, and 16). The slow wave response to the familiar class of stimuli did not differ from the slow wave response to the unfamiliar class of stimuli. Wave general habituation (habituation other than stimulus quality habituation, Appendix 6) to explain the results for the P300, P400 and negative components in the present study, similar differences would be expected for the slow wave component. The absence of a class difference for the endogenous slow wave component supports the argument that results obtained for the P300, P400 and negative components were due to cognitive processes.

7.4.3 The Negative Component

In examination of plotted individual evoked responses (vs. plots of evoked responses averaged across all subjects, Figures 1-40), a negative component was observed. The main characteristic of this component, which occurred between 440 and 680 milliseconds, was that in comparison to the unfamiliar stimuli, a peak of greater negative amplitude was observed for the familiar class of stimuli (at time one, session 3, 11 subjects displayed this component; session 4, 12; session 5, 13; at time two, session 3, 7; session 4, 10; session 5, 14). The results from the repeated measures analysis of variance were equally convincing. For channels C3, C4 and PZ, sessions 1, 2 and 3, at both time one and time two, the negative component was not significantly different by class. For sessions 4 and 5 the negative component to the familiar class of stimuli was of significantly greater negative amplitude than the response to the unfamiliar stimuli, by channel and time, Tables 11, 12, 13), (Figures 1-40).

These results indicate that with increased familiarity the negative component elicited by the familiar class of stimuli was of significantly greater amplitude than the negative component elicited by the unfamiliar stimuli.

The finding cannot be explained by general habituation or stimulus quality habituation. The significantly greater amplitude of the negative component to the familiar class of stimuli vs. the unfamiliar class was interpreted as a clear indication that this component, along with the P300 and P400 components, was indicative of cognitive processes. While further experimentation is needed to confirm the negative component observed in the present study, a speculative interpretation is offered.

Bindra (1976) and Nickerson (1978) reported, in a task requiring subjects to detect stimuli (faces) as same or different from a target set of stimuli, that a judgment of same may require more time than a judgment of different. A stimulus may be judged different upon recognition of the first characteristic not common to the target set, whereas the judgment of same requires a consideration of all characteristics. From this reasoning it is quite possible that in the present study, in addition to memorizing all slides as instructed, subjects also judged the stimuli as same (familiar) and different (unfamiliar). Were that to have occurred, and the negative component was associated with that process, then the results obtained for the negative component in the present study can be explained. The greater negative amplitude to the familiar class of stimuli at sessions 4 and 5 could suggest the process of establishing a judgment of same (familiar). Further research, however, is needed to confirm this speculative interpretation.

7.5 Summary of Conclusions and Interpretations

In the present study five evoked potential components were discussed. The N100, an exogenous component; and the P300, P400, slow wave and negative endogenous components. Both the N100 and slow wave components were found not to differ by class across the five sessions at time one time two. Based upon these findings it was concluded that differences observed in the P300, P400 and negative components could not be attributable to differences in the physical characteristics of the two classes of stimuli, general arousal level (slow habituation, Appendix 6), or fast habituation due to non-random inter stimulus intervals (Appendix 6). The results for the negative component could not be explained by stimulus quality or general habituation, and was interpreted as indicative of cognitive processes. From the results for the P300 and P400 components it was concluded that the evoked response to the familiar class of stimuli decreased significantly from the response to the unfamiliar stimuli with increased repetition (sessions 3, 4 and 5).

The most parsimonious interpretation for these findings was that the results obtained for the P300, P400 and negative components in the present study were indicative of memory processes. In the present study previously unseen stimuli became familiar, or remained unfamiliar to subjects across the five sessions. The evoked response for the P300, P400 and negative components were differentiated by class, and were not found to be the result of general stimulus habituation or experimental artifact. The findings from the present study did not support the specific interpretations proposed by Kok and Looren de Jong (1980), (i.e. stimulus categorization, continued processing, etc.). They were consistent, however, with a broader interpretation of their results as reflecting memory processes.

The significance of the present study that the methods and procedures developed provide a means by which to discriminate classes of pictorial stimuli (familiar and unfamiliar) solely upon the basis of an averaged evoked response. Previous attempts to establish such a methodology have been limited. The ability to discriminate the processing of pictorial stimuli, independent of task demands imposed by traditional performance measures, may be useful in examining hemispheric specialization (Appendix 2).

The problem of familiar landscape slides viewed as familiar in the present study is currently being studied using computer generated stimuli. The use of computer generated stimuli will allow control of similarity and dissimilarity between classes of stimuli. The manipulation of this parameter may provide an understanding for the high false positive rate (unfamiliar slides viewed as familiar) found in the present study and by Goldstein et al. (1982).

APPENDIX I

THEORIES OF VISUAL REPRESENTATION IN LONG-TERM MEMORY (LTM)

I. Introduction

Given the evidence that LTM can obtain a great deal of information about the physical attributes of items, it is not surprising that the question of how that information is represented has arisen. Theories about physical representations can be divided into two camps, dual and unitary code theories (Klatzky, 1980).

II. The Dual-Code Theory

One theory proposes that knowledge about visual events is held in LTM in a different kind of store than that which retains knowledge about verbal information. This theory is called the dual-code, or dual systems, view, and one of its principal advocates is Paivio (1969, 1971, 1978). Essentially, the theory assumes that LTM includes two systems for representing information. One, called the verbal system, is specialized for knowledge that is usually expressed in words. The other system can be thought of as analogue; that is, they are capable of representing information continuously, as a picture represents space. The two systems are assumed to be strongly connected, so that a concept represented as an image in the imaginal system can be converted to a verbal label in the other system, or vice versa.

However, the systems are also assumed to differ in certain ways. One of the most important differences is that the imaginal system deals with only certain kinds of information; it is specialized for the representation of concrete concepts, those that can readily be pictured or imagined. It would represent concepts like dog or bicycle, for example, but it would not do well with abstract concepts like truth or justice.

The dual-code theory easily accounts for the data on visual memory by assuming that information about pictures is held in the imaginal system and that codes in that system are retained particularly well. The dual-code theory also can account for data from studies comparing memory for lists of concrete and abstract verbal items. Generally, the concrete lists are better remembered. The dual-code model assumes that concrete items can be represented in both the imaginal and the verbal system, whereas abstract items are represented only in the verbal. Two memories are presumably better than one, explaining the advantage concrete verbal items show at recall over abstract ones.

There are a number of problems with the dual-code model that must be considered along with the advantages. To begin with, one must ask what mental images look like. It seems unlikely that LTM stores exact copies of visual stimuli. Pylyshyn (1973) has argued that there are many logical difficulties inherent in this idea. For instance, the storage of detailed copies of all the scenes we remember would seem to impose immense demands on LTM's capacity. Another point to consider is how we would use those stored scenes. They would somehow have to be retrieved, which would require perceiving and analyzing them. But if the stores pictures have to be reperceived before they are used, they might as well be stored as already perceived entities rather than as copies of visual events. Pylyshyn argues, using points like these, that images must exist in memory as analyzed entities rather than as raw sensory material.

Dual-code advocates concede that mental images are not like explicit copies of pictures but instead contain what has been encoded from visual displays after perceptual analysis and pattern recognition. Thus, images would be organized to segregate figures from background, representing objects as units with clearly defined contours (Kosslyn and Pomerantz, 1977). This view answers the objections to the idea that imaginal LTM stores templates of viewed scenes, without giving up the idea of imaginal LTM itself (Klatzky, 1980).

Even this version of the dual-code theory has been questioned, however. The attempt to equate images with the output of the perceptual process suffers from the fact that it is not clear just what the output is like. If it is still very like a picture, then many of the problems raised by the concept of mental images as copies of pictures still stand. For example, the processes that retrieve information from such images must be specified (see Kosslyn and Pomerantz, 1977). On the other hand, it could be assumed that the products of perception are not picturelike at all; that they resemble the LTM codes representing sentences. This assumption would constitute a unitary view, which proposes that there is a single representational format for pictorial and verbal stimuli.

III. Unitary Codes for Pictures and Words

One source of evidence for the unitary view of visual and verbal coding consists of studies indicating that meaningful interpretations of pictures, not just the remnants of perception, are stored in LTM. The work of Mandler and associates (1976, 1977), indicating that scenes are encoded with meaningful schemata, suggests this view. Further support comes from studies of memory for nonsensical pictures. Such pictures are difficult to interpret without a label, but they become meaningful when one is supplied. For example, 00 might be labeled as a pig approaching in a fog (Klatzky, 1980). When subjects are given such pictures without labels, their ability to reproduce them later is relatively poor; supplying the meaningful label improves their memory (Bower, Karlin and Dueck, 1975). Moreover, when subjects who saw such pictures with meaningful labels take part in a recognition test (that is, they must indicate which of a series of test items were previously seen pictures and which are new distractor items), they are particularly adept at detecting distractor items that change the meaning of the original, rather than those that change the original item without altering its meaning (Rafnel and Lkatzky, 1978). (In terms of the above example, 0_0 would change the meaning; 0 0 would not). This finding suggests that, during the test, subjects did not merely compare the test items with internal copies of the original pictures. Rather they were comparing what they had previously decided was in the pictures to their current interpretation. Studies like these do not attempt to refute the idea that physical details of pictures are stored, but they emphasize that semantic analysis is highly important to retention of pictorial stimuli, as it is to verbal items.

Another argument for a unitary code comes from a study by Light and Berger (1976), which casts doubt on the idea that incidental properties of words such as their typefaces are retained through mental images. They tested a rather strong version of the imagery notion, which states that if a printed word were stored as an image, the image code should contain all of the word's visual properties. For example, if the word were printed in red capital letters, the resulting image would convey both that the letters were capital and that they were red. This means that if subjects remembered one attribute of a given word, such as its color, they should also remember the other. For if one attribute were remembered, that would indicate an image had been retained, and the image would also convey the second attribute. This prediction was not confirmed, however. When subjects were given a list of words that varied in both case (whether or not they were capitalized) and color, the data indicated that the two attributes were retained independently. (This means that if it is known that the subject remembered the case of a given word, this did not better the prediction that he or she remembered its color than if it were not known whether he case was retained at all). These results argue that storage of one attribute is not tied to stage of another. Thus, the stored representation cannot be like a picture of a colored word, which would tie the color of the item to its form by representing the two together. The independent storage of the two attributes observed by Light and Berger is consistent with a more abstract representation such as a proposition, which could as readily describe either attribute alone as both, or neither.

An alternative explanation of these results might be that the words were retained as images but that the attributes of case and color could fade independently from an image. After all, a photograph can represent the form of an item without its color (Klatzky, 1980). However, Light and Berger argue against this proposal. If this were true, subjects who were instructed to remember a word's case and its meaning could afford to store the word as a colorless image. But subjects who were instructed to remember a word's color and meaning would have to store an image clear enough to read, so they would also retain information about the word's case. If both types of subjects were then tested on the attribute they were not told to remember, the remember color subjects should do better at remembering case (which was necessarily conveyed by their image) than the remember case subjects do at remembering color (which could be dropped from their image). Thus, the remember color subjects should do better on an attribute memory test. This outcome was not observed, however; the two groups performed about equally when asked to recall both case and color. In short, this study offers little support for the idea that the visual attributes of words are retained as images. Presumably, they are held as more abstract representations of the sort that can convey nonvisual attributes as well (i.e., unitary codes).

Theorists who postulate a unitary representation for visual and verbal codes in LTM generally assume that the format is propositional. Within this approach, however, theories vary in the extent to which they distinguish between the propositional representations of visual and non-visual information. One view, for example, has proposed that there are two types of propositions to represent visual and verbal items (Kieras, 1978). In contrast is the idea that there is but one type of proposition. According to the latter view, one can speak of visual and verbal codes, but the differences between them are minimal, pertaining only to the content of the information they convey. That is, the one proposition theory states that all propositions convey information about the meaning of items. Sometimes that meaningful information is about an item's physical appearance; sometimes it is not. But even if a proposition conveys physical attributes, it still represents an interpretation of those attributes, and is essentially the same as the representation of a sentence about those attributes.

Theorists who do not make a distinction between propositions representing visual and nonvisual inputs must still explain data which suggests that visual and nonvisual information are dealt with differently in LTM. One approach is to reinterpret the data so as to minimize the differences between the visual and non-visual domains. For example, consider the phenomenon of very robust long-term retention of pictures. To counter this evidence for visual/verbal storage differences, it has been argued that studies overestimate the capacity for remembering pictures. For one thing, such studies have usually used recognition tests on which subjects could perform adequately even if they remembered little about the appearance of a picture. The distractor items (new items which the subject is to discriminate from previously seen pictures) are from a different class than the original pictures, which would allow accurate performance if subjects remembered only the concept represented by the picture and not the picture itself. In support of this argument is the finding that picture recognition is not nearly so accurate when items are all drawn from a highly similar pool. When subjects were presented with as few as 14 pictures of snowflakes, for example, their recognition performance was only 36 percent accurate on a test (with snowflake distractors) immediately following presentation (Goldstein, Chance, 1970). This is rather different from the 90 per cent of greater accuracy with several hundred pictures observed in other studies.

Another argument that has been offered to explain the generally good memory for pictures is that pictures contain more information than their corresponding labels. If part of the information in a picture is forgotten, therefore, it will still be discriminable from distractors on a recognition test because enough other information remains. In contrast, forgetting of part of a word will make it highly similar to other words, leading to recognition errors. If it is assumed that the extra information in a picture that leads to better memory is stored propositionally, like any other information, this argument can account for high rates of picture recognition within the one proposition model.

An experiment by Nelson, Metzler, and Reed (1974) offers some support for the one proposition model by providing evidence that subjects' ability to remember pictures does not necessarily mean they store highly specific visual details about them. Nelson et al. constructed four types of stimuli for the same scenes. A given scene was represented by a photograph, a one-phrase description of the photo, a detailed drawing of the photo, and a nondetailed drawing of it. Each subject viewed one of the four types of stimuli and was then given a recognition test, where the stimuli were to be discriminated from distractors not seen before. Nelson et al. found that recognition performance for any pictorial stimuli (photo, detailed drawing, nondetailed drawing) was better than that for the verbal description; this is the usual pictorial capacity effect. However, the recognition scores for the various types of pictorial stimuli did not differ from each other; that is, amount of detail did not affect recognition. This suggests that the superior memory for pictures is not due to their being stored in LTM as detailed copies, for in that case greater detail should have led to better performance. The fact that recognition was as good for nondetailed pictures as for detailed pictures is consistent with the idea that subjects store interpretations of the stimuli, since interpretations could be sufficiently abstract that they would describe nondetailed and detailed pictures equally.

The large capacity of picture memory is not the only phenomenon that one proposition theorists must explain; another is the superiority of memory for lists of concrete items over memory for abstract items. It has been suggested that the two types of items differ on more than just concreteness. Concrete and abstract words may also in complexity or in the number of meanings they have (Anderson and Bower, 1973); sentences made up of concrete words may be comprehensible than those made up of abstract words (Johnson, Bransford, Nyber, and Cleary, 1973). These alternative explanations of concreteness effects seem intuitively plausible; however, when experimenters control for differences other than concreteness between such items, for example, by comparing concrete and abstract words rated as equal in meaningfulness, effects of concreteness are not eliminated (Moeser, 1974; Paivio, Yuille, and Rogers, 1969). Concreteness effects have proven rather difficult to explain in terms of other attributes (Kieras, 1978).

The difficulty of showing that the concreteness variable is really due to some other underlying difference between words is a problem for the one proposition view. Another problem comes from studies in which subjects take part in tasks that require them to form and manipulate mental images. For example, it has been reported that the time required for rotating an image varies with the distance in space over which it is to be rotated (Kosslyn, Bali, and Reiser, 1978). These effects are found even when subjects are given a verbal label and generate the images from information in LTM, so that they must reflect the content of visual information stored there.

The problem posed by these findings is how can the visual codes they suggest exist in LTM as propositions, especially when those propositions are the same type that convey the meanings of sentences. Consider, for example, the following picture: * +. A verbal interpretation of this picture might be that it is a star and a cross on the same axis. This description would not convey the distance between the star and the cross. Yet, from the study of Kosslyn, Baki and Reiser (1978), if subjects are required to form an image of the star and the cross and scan that image, the time required would depend on the actual distance between the star and the cross. In short, the idea that visual information in LTM is at an abstract interpreted level seems somewhat at odds with the visual details that information seems to convey.

APPENDIX 2
GENERAL CONSIDERATIONS FOR COMPLEX PICTORIAL STIMULI

I. Introduction

As pointed out by Sergent and Bindra (1981), until recently, there have been two general propositions about the recognition of complex pictorial stimuli that have been accepted in the literature. One has been that the recognition of complex pictorial stimuli (such as faces and scenes) is primarily a right hemisphere function. This proposition arose from the early finding that right hemisphere but not left hemisphere damage results in a loss of capacity for visual pattern recognition and has found some support in the lateralization studies of face recognition with normal human subjects (Sergent and Bindra, 1981). The second proposition is that face recognition in a specific and unitary function, which is distinct from other forms of visual pattern recognition (for example, landscapes). This proposition was prompted by documented cases of prosopagnosia, a specific inability to recognize familiar persons visually, and has drawn some support from the notion that evolutionary pressures may have shaped special perceptual mechanisms for adaptively significant patterns such as faces (Sergent and Bindra, 1981). Though the two propositions are independent and their truth or falsity are separate questions, jointly they have promoted the emergence of complex pictorial stimuli, and in particular facial recognition, as a special research area. Within this area two general questions have been pursued: one question has been what, if any, differential hemispheric involvement can be inferred from performance measures (typically accuracy, and reaction time, RT) obtained from the presentation of pictorial stimuli (primarily faces) to the visual half fields in a recognition task; the other general question has been whether the recognition of facial stimuli reflects different processing mechanisms than those for other types of pictorial stimuli (Sergent and Bindra, 1981).

As was already indicated, previous answers to these two questions suggested that the right and not the left hemisphere was responsible for the processing of pictorial stimuli, including faces; and that facial recognition appeared to be processed by mechanisms distinctly different from those for other types of pictorial stimuli (Sergent and Bindar, 1981). However, more recent evidence suggests that the left hemisphere is also implicated in the processing of pictorial stimuli (i.e., visual pattern, or visuospatial stimuli) (Hecaen and Assal, 1970; Benton, 1980; Levine, 1978; Meadows, 1974). In a recent review by Sergent and Bindra (1981) support for viewing facial recognition processes as distinctly different from the processes for other types of pictorial stimuli is challenged. Sergent and

Bindra (1981) suggest that support for unilateral right hemisphere responsibility in the processing of pitroial stimuli (in particular, faces), and the proposition that facial processing is unique, may in fact be due to methodological considerations as opposed to real information processing differences. In part, this may be due to the fact that researchers have not always been clear and/or consistent in what they have meant by the term "recognition." As the use of recognition tasks are predominant in the study of complex pictorial stimuli, a closer examination of the paradigms used in this area is necessary in order to interpret their results and limitations.

II. What is Meant by Recognition?

The term recognition is often used vaguely. At times it refers to tasks that require only a perceptual (discriminative) judgment; at other times it implies judgments of varying degrees of familiarity (Mandler, 1980). Investigations of the differential involvement of the cerebal hemispheres during processing of pictorial stimuli have been conducted with three main types of tasks: 1) perceptual discrimination tasks, wherein subjects have to decide, using faces, for example, whether tow simultaneously presented faces are the same or different (Moscovitch, Scullion, and Christie, 1976; experiment 1); 2) recognition tasks, in which subjects have to judge whether a presented stimuli is the same as a target stimuli seen earlier (Hilliard, 1973) or to select, from a set of distractor stimuli, the one seen earlier (Leehey and Cahn, 1979); and 3) identification tasks, again using faces, for example, wherein subjects are required to recognize a physiognomy as belonging to a previously specified individual (Marizi and Berlucchi, 1977).

An element which is common to the perceptual, recognition, and identification tasks is the tachistoscopic presentation of one or two pictorial stimuli in one visual field; that is, to the left or right of a central fixation point. So long as the central fixation is maintained, stimuli in the left visual field (LVF) and right visual field (RVF) are projected to the right and left hemiretinae, respectively. To ensure this, it is important to reduce the duration of tachistoscopic exposure to less than that required to change gaze away from the central fixation point. Owing to the neuroanatomical organization of the optic chiasm, the ganglion cells of the tow right hemiretinae project to the right hemisphere (RH), and those of the left hemiretinae project to the left hemisphere (LH). Thus, stimuli in the LVF are initially projected to the RH, and those in the RVF are similarly projected to the LH. To ensure that stimuli in each visual hemifield are not projected to both hemispheres, the stimuli must be presented to the left or right of the central fixation point. When these conditions are met, any advantage in the perception, recognition, or identification of stimuli in the LVF or RVF have been equated with an RH or LH advantage, respectively. Such lateralized presentation of stimuli means brief exposure time and nonfoveal viewing, and these conditions may have particular consequences in the different types of tasks (Sergent and Bindra, 1981).

Another element common to the perceptual and recognition tasks, but not to the identification, is that perceptual discrimination and recognition involve same or different judgments and require the presentation, either simultaneously or successively, of a target and a test stimuli. This creates two specific conditions. First, using faces to illustrate the point, faces to be compared are part of a fixed set and are exposed either together or in quick succession. Second, the comparison of the two faces does not require that each be examined fully, but may be performed on the basis of some features only, especially when the faces differ along several dimensions (Sergent and Bindra, 1981). There are several views about the types of processes that may be involved in the making of same and different judgments (Bindra, 1976, chapter 13; Nickerson, 1978), but there appears to be general agreement that a different judgment may be reached as soon as one difference is detected, whereas a same judgment typically requires that stimuli be compared on all their dimensions. Thus, when an unspecified set of stimuli is used, a comparison of several features may be involved. However, this need not be so when only a small set is repeatedly used. With faces, for example, if the style of haircut is the same in two presented faces, it may be immediately concluded that the faces are the same if the subject knows that, in the set of faces being used, no two faced have the same hair style (e.g., Ceffen, Bradshaw, and Wallace, 1971, Exp. 1). This means that even a same judgment can be made on the basis of examining only limited parts of the stimuli. On the other hand, with faces, for example, identification tasks usually involve the presentation of only one face drawn from an unknown large set and require a specific identifying response based on varying component features of unexpected (but familiar) face. Thus, although perceptual discrimination and recognition tasks may involve no more than comparing stimuli from a known set along some specific dimensions, identification tasks impose more stringent requirements for judgment.

With these considerations in mind, it will be useful to examine the recognition task, main variables an their parameters, as this task has been used extensively to support 1) the position that differential hemispheric processing of pictorial stimuli occurs; 2) that facial recognition is a distinct type of pictorial recognition.

III. Recognition Tasks

Most evidence of a RH specialization for processing complex pictorial stimuli such as faces in normal subjects has been drawn from recognition studies. As previously mentioned, recognition experiments involve matching a test stimulus to a target stimulus seen earlier. Typically, the comparison between two faces is made in the absence of the visual trace of the target face, after the iconic image of the target face has disappeared (between 50 and 100 msec, Moscovitch et al., 1976). This involvement of memory distinguishes recognition tasks from perceptual discrimination tasks (Sergent and Bindra, 1981).

IV. Main Variables

Two main variables have been used in recognition studies: speed, as measured by response latency (RT studies): and accuracy, indicated by the number or percentage of correct responses (accuracy studies). It is possible to identify four parameters whose values have been manipulated and specified in RT or accuracy studies (Sergent and Bindra, 1981).

A. Exposure Duration. The duration of tachistoscopic exposure is chosen according to different criteria in RT and in accuracy experiments, with the common restriction that it be short enough to prevent eye movements from the fixation point to the stimulus display. In RT studies, errors must be minimized so that the latency measures will be reliable.

Given a certain stimulus intensity, stimulus presentation must be of sufficient duration ot insure accurate detection in either visual field. With this precaution, hemispheric differences in response latencies are probably no attributable to errors and have been taken to result from differential processing time between the two hemispheres (e.g., Moscovitch et al., 1976). This requirement of reducing errors by adequate exposure duration may explain why no RT study so far has reported hemispheric differences in the number of errors. On the other hand, exposure duration in recognition accuracy studies is usually short enough to result in an appreciable number of errors, presumably owing to only partial encoding of the stimulus. Thus, RT experiments allow a processing based on clear visual traces, whereas accuracy experiments require processing of partial or degraded visual stimuli. It is usually assumed that the more specialized hemisphere would need a lesser amount of information to perform accurately.

B. Stimulus Characteristics. Both RT and accuracy recognition experiments are conducted with pictorial stimuli, such as faces, that are unfamiliar to the subject prior to the experiment. In general, most investigators use artificially constructed scenes or faces, varying their stimuli along specific features (for example, with faces, the eyes, ears, etc.). Stimuli typically differ on several dimensions and are easily discriminable. Accuracy studies, for the most part, have used photographs of real scenes or faces without much attempt at controlling their degree of similarity. For example, one may compare the highly discriminable faces used by Geffen et al. (1971, p. 417) in an RT experiment with the less discriminable faces used by Milner (1968, p. 196ff) as typical in accuracy studies (Sergent and Bindra, 1981).

C. Stimulus Set. RT studies have tended to use only a few target test stimuli. Geffen et al. (1971, Experiment 1), Moscovitch et al. (1976, Experiment 2), and Patterson and Bradshaw (1975, Experiment 2 and 3) used only one target stimuli. Rizzolatti, Umilta, and Berlucchi (1977) used two. A small number of test stimuli (4 or 5) were used for the recognition test in these experiments. Conversely, recognition accuracy studies use a large number of target stimuli: Hilliard (1973) used 96; Jones (1979), 60, Finlay and French (1978), 40; and Ellis and Shepherd (1975), 36. Usually an equal number of nontarget stimuli is included to complete the test stimulus set. The target stimuli are usually presented only once as target and once as test.

D. Delay Interval. RT studies involve some form of retention of the target stimuli for a short period just prior to the test trials. In accuracy studies this delay interval has been varied from 500 msec (Hilliard, 1973) to 48 hours (Jones, 1979).

Although particular values of these four parameters may be selected to obtain meaningful data, they do influence the results obtained and the interpretations they invite (Sergent and Bindra, 1981). For example, it may be that these parameters and their interaction within a specific type of experiment have influenced speed and accuracy measures, making it difficult to say how far the reportedly more efficient recognition of complex pictorial stimuli, such as faces, in the LVF is attributable to a genuine RH superiority in the processing of physiognomies per se. Consider the two types of studies.

V. Reaction Time Studies

These studies are designed to determine which visual hemifield yields faster recognition of pictorial stimuli. Moscovitch et al. (1976, Experiment 2), replicating Geffen et al.'s (1971, Experiment 1) study, found an LVF superiority for same-different judgments in comparisons of test faces with a memorized target face. Using a set of four faces, they found that field differences in response times did not appear as long as the interval between target and test presentations was less than 100 msec. With intervals of 100 and 1,000 msec, a clear LVF advantage emerged. The authors suggested that once the short-lived trace of the target stimulus decays, the test face must be compared with a more permanent memory representation to which RH has preferential access or on which the RH can operate more efficiently. However, an alternative interpretation in terms of procedural variables is possible (Sergent and Bindra, 1981)

There is evidence that the memory representation of an unfamiliar pictorial stimuli decays with time but that this decay does not affect all features equally. Walker-Smith (1978) varied the delay interval between target exposure and test presentation of faces at a central fixation point. She found that as the delay interval increased, the inner features were more susceptible to fading, leaving the memory representation of the face in terms of its external contours. In another experiment, Davies, Ellis, and Shepherd (1977) showed that, when very dissimilar faces are compared, the hair and the chin contours were the two most salient features on which the comparison could be most accurately made. These findings suggest that longer delay intervals and highly discriminable stimuli would favor a comparison in terms of the main contours of those stimuli. Such a comparison is likely to be more holistic than analytic and may, according to holistic-analytic hypothesis of RH-LH differences (Levy-Agresti and Sperry, 1968), be responsible for the RH superiority found in the Moscovitch et al. (1976) experiment (Sergent and Bindra, 1981). Thus, it is not necessary to attribute greater mnemonic efficiency to the RH.

There is also evidence that when pictorial stimuli differing only in some nonsalient features are used, the task may require serial analysis of all the features before a judgment can be made; according to the holistic-analytic hypothesis, such a task would involve the LH. Patterson and Bradshaw (1975, Experiment 3) used schematic faces made of geometric shapes (circle, elongated rectangle, cross) as the inner features and presented subjects with a target face to be compared with test faces differing on only one inner feature. They obtained a RVF (LH) advantage for both same and different judgments and concluded that an LH analytic type of processing was involved in recognition of faces differing on a limited number of features. The argument that this LH advantage could be due to the possible use of verbal codes in memorizing the features of the target stimuli is ruled out by the finding of an LVF (RH) superiority when the same target was used with more dissimilar test stimuli (Patterson and Bradshaw, 1975, Exp. 2). Thus, an RVF (LH) superiority can be demonstrated in some cases of recognition when the discriminability of the pictorial stimuli is low and the task difficulty high.

It is reasonable to conclude that the usual LVF (RH) advantage found in RT recognition studies with normal subjects results from the use of highly discriminable stimuli; use of less discriminable stimuli may lead to an RVF (LH) advantage (Sergent and Bindra, 1981). The reported

LVF superiority is thus not inherent in the processing of pictorial stimuli as such, but in the processing of certain types of pictorial stimuli under specific circumstances. The findings suggest that both hemispheres may contribute to the processing of complex pictorial stimuli, including faces, but that in recognition studies, the role of the LH may be hidden by a faster RH holistic processing in the easy recognition tasks typically used in the relevant experiments. Thus, it is possible that there may be no hemispheric differences in the acquisition of pictorial stimuli, but that a right hemisphere superiority results from subsequent task demands (i.e., performance in a recognition task) after stimulus acquisition. In order to examine this possibility a measure of the acquisition of pictorial stimuli, without the potential confound introduced from task demands, would be extremely useful. Furthermore, experiments with systematic variation of discriminability of pictorial stimuli are also needed (Sergent and Bindra, 1981).

VI. Accuracy Studies

In recognition accuracy experiments a target stimuli is exposed, and one or more test stimuli are subsequently presented; the subjects are required to decide whether they have seen the test stimuli before. In some cases (Finlay and French, 1978; Jones, 1979), a target face was presented at a central fixation point, and the test face was later briefly flashed in one visual field. In some other studies, the target was presented in one hemifield, and the test later appeared in the middle of the visual field (Ellis and Shepherd, 1975; Hilliard, 1973). Yet another procedure consisted of presenting the target in one visual field and asking the subject to recognize it within a set of distractors (Leehey and Cahn, 1979). In all experiments, a LVF superiority was found. These experiments involved a very brief exposure and delay between the presentations of the target and test stimuli (8 msec, Finlay and French, 1978; 15 msec, Ellis and Shepherd, 1975; up to 120 msec, Leehey and Cahn, 1979), and a large number of stimuli that were seen only once. Although all these conditions seem to be required for conducting recognition accuracy, their combination may determine the reported LVF (RH) advantage (Sergent and Bindra, 1981). That is, assuming that RH processes holistically, it may therefore be expected to be better suited for processing partial, degraded or ambiguous information.

There is some evidence to support this suggestion. Walker-Smith (1978) studied the effects of exposure duration on encoding the different features of a face and found that decreasing exposure duration resulted in reduced accuracy in encoding the inner features of a face. Rizzolatti and Buchtel (1977) found that LVF advantage could be enhanced by a similar decreased in exposure duration. Moreover, as noted earlier, Walker-Smith also found that, with increasing temporal separation of the target and test presentations, the inner features were more susceptible to decay than the outer features. Thus, the interaction of short exposure and delay, factors inherent in accuracy studies, may require that a holistic comparison be made on the basis of degraded stimulus information; whatever the procedure used in the accuracy studies described earlier, it involved a trace (target or test) that was decayed or partial or both. What is tested in these experiments, then, may not be primarily the relative capacity of the cerebral hemispheres to process pictorial stimuli but the ability of the hemispheres to deal with degraded information (Sergent and Bindra, 1981). At such a task, the RH has been shown to be superior to the LH by Warrington and James (1967) in tests involving incomplete representations of objects and animals and by Newcombe (1969) in a closure task. It cannot therefore be concluded from these accuracy studies that the LH has a lesser capacity to process pictorial stimuli than does the RH. The result of these experiments could mean that the LH needs clear and complete information to perform the type of processing for which it may be specialized (Sergent and Bindra, 1981). In fact, when slightly longer exposure duration is used, as in the RT studies cited earlier, there is no difference in recognition accuracy between LVF and RVF presentations.

VII. Summary and Comment on Recognition Studies

It may thus be concluded from recognition studies with normal subjects that the LVF and RVF superiority effects depend on several procedural conditions. For example, there is no evidence that LVF advantage for processing facial physiognomies is inherent and absolute. The findings are consistent with the generalization that, when a target stimuli has to be kept in memory, an LVF latency advantage is seen under conditions of easy recognition tasks involving very dissimilar stimuli, and LVF accuracy advantage is seen under conditions of degraded stimulus information (short exposure and long interstimulus delay); RVF advantage may be seen under the reverse conditions (Sergent and Bindra, 1981).

The preceding review of the experiments on laterality effects during performance on a complex pictorial recognition task, such as facial recognition, points to some tentative conclusions (Sergent and Bindra, 1981). The experimental results examined here indicate that several procedural factors favor the outcome of an LVF advantage in the processing of pictorial stimuli. Furthermore, most of the procedural factors that favor the emergence of an LVF advantage are to some extent dictated by the nature of the experiment; hence the preponderance of studies showing an LVF advantage. Thus, the results from these studies can be meaningful compared and interpreted only by paying close attention to the experimental materials and procedures used (Sergent and Bindra, 1981).

Yet, while the apparent LVF advantage for pictorial stimuli may be due to methodological factors, it is also possible that the advantage is real. As the examination of this right hemisphere superiority from investigating performance on recognition memory tasks (i.e., reaction times and accuracy) have demonstratedly led to ambiguous results, an examination of earlier memory processes is indicated.

APPENDIX 3

PROCEDURES FOR RELATIVE LOG FOOT LAMBERT MEASUREMENT

Two hundred fifty slides were cleaned using Kodak film cleaner (195-6986) and blown dry with compressed air. Log foot lambert measurements were taken with an SEI exposure meter, and a relative log foot lambert measurement for each slide was obtained by the following procedure:

I. The illumination for a black slide was obtained and found to be .76 foot candles;

II. the illumination for the same blank slide was also obtained and found to be 2.

III. the illumination for each of 250 slides was obtained;

IV. the measure of illumination for each slide (foot candles) was divided by the measure of illumination for the blank slide (.76 foot cancels); this quotient was then multiplied by the measure of llumination for the blank slide (2.92 log foot lamberts); this resulted in a measure of log foot lamberts relative to the blank slide;

V. the mean value for the 250 slides was 1.15 log foot lamberts, with a standard deviation of .206 log foot lamberts.

APPENDIX 4

SLIDE SEQUENCE FOR THE 5 EXPERIMENTAL SESSIONS (TRIALS)

The 200 slides were randomly assigned to 1 of 5 sets (F_1, UF_{1-4}). Within each of the 5 experimental sessions 80 slides were presented to each subject (40 from set F_1 and 40 from a UF set). For each of the 5 experimental sessions a different random order for the presentation of the 80 slides was used. For each session the following sets were presented:

Session 1, 40 slides from set F_1, previously unseen and
40 slides from set UF_1, previously unseen

80 slides were presented in random order;

Session 2, 40 slides from set F_1, previously seen once (Session 1)
40 slides from set UF_1, previously seen once (Session 1)

80 slides were presented in random order;

Session 3, 40 slides from set F_1, previously seen twice (Sessions 1 and 2)
40 slides from set UF_2, previously unseen

80 slides were presented in random order;

Session 4, 40 slides from set F_1 previously seen 3 times (Sessions 1 and 2, and 3)
40 slides from set UF_3, previously unseen

80 slides were presented in random order;

Session 5, 40 slides from set F_1, previously seen 4 times (Sessions 1, 2, 3, and 4)

40 slides from set UF_4, previously unseen

80 slides were presented in random order;

over the 5 Sessions:

set F_1 of 40 slides was presented 5 times;
set UF_1 of 40 slides was presented 2 times;
set UF_2 of 40 slides was presented 1 time;
set UF_3 of 40 slides was presented 1 time;
set UF_4 of 40 slides was presented 1 time.

This resulted in 400 individual stimulus presentations to each subject.

APPENDIX 5

TABLES OF RESULTS FROM THE REPEATED MEASURES ANALYSIS OF VARIANCE FOR CHANNELS C4, C3 AND PF.

TABLE 17

MEAN MICROVOLT AMPLITUDE BY TIME, SESSION AND CLASS FOR THE N100 EVOKED POTENTIAL COMPONENT RECORDED AT CHANNEL C3, N = 17.

Time	Session	Class	Mean Microvolt Amplitude
T1	1	F	7.1
T1	1	UF	7.2
T1	2	F	5.0
T1	2	UF	3.2
T1	3	F	3.4
T1	3	UF	4.3
T1	4	F	3.5
T1	4	UF	2.1
T1	5	F	-1.0
T1	5	UF	-1.5
T2	1	F	8.6
T2	1	UF	6.9
T2	2	F	5.6
T2	2	UF	5.4
T2	3	F	5.1
T2	3	UF	6.1
T2	4	F	4.5
T2	4	UF	4.2
T2	5	F	1.7
T2	5	UF	5.9

TABLE 18

RESULTS FROM A DUNCAN'S MULTIPLE RANGE TEST PERFORMED ON THE MAIN EFFECT DUE TO SESSION; N100 MEAN, CHANNEL = C3

Grouping			Session	Mean Microvolt Amplitude
A			1	7.5
A	B		2	4.8
A	B		3	4.7
	B	C	4	3.6
		C	5	1.3

TABLE 19

MEAN MICROVOLT AMPLITUDE BY TIME, SESSION AND CLASS FOR THE N100 EVOKED POTENTIAL COMPONENT RECORDED AT CHANNEL C4, N = 17.

Time	Session	Class	Mean Microvolt Amplitude
T1	1	F	-0.3
T1	1	UF	-1.8
T1	2	F	-4.1
T1	2	UF	-4.4
T1	3	F	-5.4
T1	3	UF	-4.0
T1	4	F	-7.7
T1	4	UF	-5.3
T1	5	F	-10.5
T1	5	UF	-9.4
T2	1	F	-1.9
T2	1	UF	-1.2
T2	2	F	-4.2
T2	2	UF	-4.0
T2	3	F	-3.1
T2	3	UF	-4.2
T2	4	F	-6.4
T2	4	UF	-6.4
T2	5	F	-6.4
T2	5	UF	1.2

TABLE 20

RESULTS FROM A DUNCAN'S MULTIPLE RANGE TEST PERFORMED ON THE MAIN EFFECT DUE TO SESSION; N100 MEAN, CHANNEL = C4

Grouping			Session	Mean Microvolt Amplitude
A			1	-1.4
A	B		2	-4.2
A	B		3	-4.2
	B	C	4	-6.3
		C	5	-6.4

TABLE 21

MEAN MICROVOLT AMPLITUDE BY TIME, SESSION AND CLASS FOR THE N100 EVOKED POTENTIAL COMPONENT RECORDED AT CHANNEL PZ, N = 17

Time	Session	Class	Mean Microvolt Amplitude
T1	1	F	-24.4
T1	1	UF	-27.1
T1	2	F	-25.5
T1	2	UF	-25.1
T1	3	F	-30.0
T1	3	UF	-25.2
T1	4	F	-32.6
T1	4	UF	-24.1
T1	5	F	-29.4
T1	5	UF	-33.2
T2	1	F	-21.1
T2	1	UF	-22.5
T2	2	F	-25.9
T2	2	UF	-23.0
T2	3	F	-24.6
T2	3	UF	-24.8
T2	4	F	-23.5
T2	4	UF	-21.2
T2	5	F	-27.5
T2	5	UF	-21.0

TABLE 22

MEAN MICROVOLT AMPLITUDE BY TIME, SESSION AND CLASS FOR THE P300 EVOKED POTENTIAL COMPONENT RECORDED AT CHANNEL C3, N = 17

Time	Session	Class	Mean Microvolt Amplitude
T1	1	F	-23.9
T1	1	UF	-24.2
T1	2	F	-23.0
T1	2	UF	-21.0
T1	3	F	-17.3
T1	3	UF	-23.4
T1	4	F	-18.7
T1	4	UF	-22.2
T1	5	F	-17.4
T1	5	UF	-23.2
T2	1	F	-28.8
T2	1	UF	-25.6
T2	2	F	-24.9
T2	2	UF	-22.7
T2	3	F	-23.5
T2	3	UF	-25.3
T2	4	F	-20.3
T2	4	UF	-25.7
T2	5	F	-21.1
T2	5	UF	-23.2

TABLE 23

RESULTS AND FOLLOW-UP ANALYSIS FROM A REPEATED MEASURES ANALYSIS OF VARIANCE PERFORMED ON THE MEAN AMPLITUDE OF THE P300 EVOKED POTENTIAL COMPONENT RECORDED AT CHANNEL C3, N = 17

Main Effect	Mean Microvolt Amplitude	p Value
Session	= 22.6	p = 0.002**
Class	F = 21.6	p = 0.003**
	UF = 23.6	
Time	T1 = 24.1	p = 0.02*
	T2 = 21.1	
Interaction Effect		
Session by Class		p = 0.07
Session by Time		p = 0.83
Class by Time		p = 0.11
Session by Class by Time		p = 0.77

*Significant at the 0.05 level.

**Significant at the 0.005 level.

TABLE 24

MEAN MICROVOLT AMPLITUDE BY TIME, SESSION AND CLASS FOR THE P300 EVOKED POTENTIAL COMPONENT RECORDED AT CHANNEL C4, N = 17.

Time	Session	Class	Mean Microvolt Amplitude
T1	1	F	20.7
T1	1	UF	20.1
T1	2	F	14.0
T1	2	UF	14.1
T1	3	F	11.6
T1	3	UF	18.4
T1	4	F	13.9
T1	4	UF	15.3
T1	5	F	11.3
T1	5	UF	18.6
T2	1	F	23.3
T2	1	UF	23.0
T2	2	F	17.9
T2	2	UF	17.5
T2	3	F	16.2
T2	3	UF	19.2
T2	4	F	14.2
T2	4	UF	20.6
T2	5	F	13.5
T1	5	UF	17.6

TABLE 25

RESULTS AND FOLLOW-UP ANALYSIS FROM A REPEATED MEASURED ANALYSIS OF VARIANCE PERFORMED ON THE MEAN AMPLITUDE OF THE P300 EVOKED POTENTIAL COMPONENT RECORDED AT CHANNEL C4, N = 17

Main Effect	Mean Microvolt Amplitude	p Value
Session	= 17.0	p = 0.001**
Class	F = 15.6	p = 0.001**
	UF = 18.5	
Time	T1 = 15.8	p = 0.06
	T2 = 18.3	
Interaction Effect		
Session by Class		p = 0.06
Session by Time		p = 0.86
Class by Time		p = 0.58
Session by Class by Time		p = 0.40

**Significant at the 0.05 level.

TABLE 26

MEAN MICROVOLT AMPLITUDE BY TIME, SESSION AND CLASS FOR THE P300 EVOKED POTENTIAL COMPONENT RECORDED AT CHANNEL PZ, N = 17.

Time	Session	Class	Mean Microvolt Amplitude
T1	1	F	-1.7
T1	1	UF	-2.1
T1	2	F	-7.0
T1	2	UF	-6.0
T1	3	F	-9.7
T1	3	UF	0.2
T1	4	F	-6.1
T1	4	UF	-2.0
T1	5	F	-7.3
T1	5	UF	-1.6
T2	1	F	4.8
T2	1	UF	2.9
T2	2	F	0.2
T2	2	UF	0.4
T2	3	F	-3.1
T2	3	UF	1.1
T2	4	F	0.1
T2	4	UF	4.5
T2	5	F	-7.1
T1	5	UF	-0.1

TABLE 27

RESULTS AND FOLLOW-UP ANALYSIS FROM A REPEATED MEASURES ANALYSIS OF VARIANCE PERFORMED ON THE MEAN AMPLITUDE OF THE P300 EVOKED POTENTIAL COMPONENT RECORDED AT CHANNEL PZ, N = 17

Main Effect	Mean Microvolt Amplitude	*p* Value
Session	= -2.0	*p* = 0.10
Class	F = -3.7	*p* = 0.001**
	UF = -0.3	
Time	T1 = -4.3	*p* = 0.005**
	T2 = 0.4	
Interaction Effect		
Session by Class		*p* = 0.07
Session by Time		*p* = 0.37
Class by Time		*p* = 0.47
Session by Class by Time		*p* = 0.93

**Significant at the 0.005 level.

TABLE 28

MEAN MICROVOLT AMPLITUDE BY TIME, SESSION AND CLASS FOR THE PEAK P400 EVOKED POTENTIAL COMPONENT RECORDED AT CHANNEL C3, N = 17.

Time	Session	Class	Mean Microvolt Amplitude
T1	1	F	0.7
T1	1	UF	0.4
T1	2	F	0.8
T1	2	UF	0.7
T1	3	F	0.3
T1	3	UF	0.7
T1	4	F	0.0
T1	4	UF	1.2
T1	5	F	0.6
T1	5	UF	1.2
T2	1	F	1.4
T2	1	UF	1.1
T2	2	F	1.4
T2	2	UF	1.2
T2	3	F	0.9
T2	3	UF	0.8
T2	4	F	0.9
T2	4	UF	1.4
T2	5	F	0.7
T1	5	UF	1.4

TABLE 29

RESULTS AND FOLLOW-UP ANALYSIS FROM A REPEATED MEASURES ANALYSIS OF VARIANCE PERFORMED ON THE MEAN AMPLITUDE OF THE PEAK P400 EVOKED POTENTIAL COMPONENT RECORDED AT CHANNEL C3, N = 17

Main Effect	Mean Microvolt Amplitude	*p* Value
Session	= 0.9	*p* = 0.55
Class	F = 0.8	*p* = 0.18
	UF = 1.0	
Time	T1 = 0.7	*p* = 0.052
	T2 = 1.1	
Interaction Effect		
Session by Class		*p* = 0.01*
Session by Time		*p* = 0.78
Class by Time		*p* = 0.39
Session by Class by Time		*p* = 0.80

*Significant at the 0.05 level.

The Session by class interaction was further analyzed by using a repeated measures analysis of variance with one within - subjects factors, class (Table 8.)

TABLE 30

MEAN MICROVOLT AMPLITUDE BY TIME, SESSION AND CLASS FOR THE PEAK P400 EVOKED POTENTIAL COMPONENT RECORDED AT CHANNEL C4, N = 17

Time	Session	Class	Mean Microvolt Amplitude
T1	1	F	-0.2
T1	1	UF	-0.7
T1	2	F	-0.7
T1	2	UF	-0.1
T1	3	F	-0.5
T1	3	UF	-0.1
T1	4	F	-0.6
T1	4	UF	+0.2
T1	5	F	-0.5
T1	5	UF	+0.2
T2	1	F	0.6
T2	1	UF	0.1
T2	2	F	0.4
T2	2	UF	0.4
T2	3	F	-0.3
T2	3	UF	-0.0
T2	4	F	-0.4
T2	4	UF	+0.3
T2	5	F	-0.1
T1	5	UF	+0.3

TABLE 31

RESULTS AND FOLLOW-UP ANALYSIS FROM A REPEATED MEASURES ANALYSIS OF VARIANCE PERFORMED ON THE MEAN AMPLITUDE OF THE PEAK P400 EVOKED POTENTIAL COMPONENT RECORDED AT CHANNEL C4, N = 17

Main Effect	Mean Microvolt Amplitude	p Value
Session	= -0.1	p = 0.96
Class	F = -0.2	p = 0.03*
	UF = 0.1	
Time	T1 = 0.3	p = 0.06
	T2 = 0.1	
Interaction Effect		
Session by Class		p = 0.05*
Session by Time		p = 0.37
Class by Time		p = 0.38
Session by Class by Time		p = 0.91

*Significant at the 0.05 level.

The Session by class interaction was further analyzed by using a repeated measures analysis of variance with one within - subjects factors, class (Table 9.)

TABLE 32

MEAN MICROVOLT AMPLITUDE BY TIME, SESSION AND CLASS FOR THE PEAK P400 EVOKED POTENTIAL COMPONENT RECORDED AT CHANNEL PZ, N = 17

Time	Session	Class	Mean Microvolt Amplitude
T1	1	F	-0.2
T1	1	UF	-0.2
T1	2	F	-0.4
T1	2	UF	-0.7
T1	3	F	-0.9
T1	3	UF	-0.4
T1	4	F	-0.9
T1	4	UF	+0.3
T1	5	F	-0.0
T1	5	UF	+0.0
T2	1	F	0.1
T2	1	UF	-0.6
T2	2	F	0.2
T2	2	UF	0.0
T2	3	F	-0.2
T2	3	UF	-0.3
T2	4	F	-0.6
T2	4	UF	0.1
T2	5	F	-0.8
T1	5	UF	0.6

TABLE 33

RESULTS AND FOLLOW-UP ANALYSIS FROM A REPEATED MEASURES ANALYSIS OF VARIANCE PERFORMED ON THE MEAN AMPLITUDE OF THE PEAK P400 EVOKED POTENTIAL COMPONENT RECORDED AT CHANNEL PZ, N = 17

Main Effect	Mean Microvolt Amplitude	$\underline{p}$ Value
Session	= -0.3	$\underline{p}$ = 0.90
Class	F = -0.5	$\underline{p}$ = 0.07
	UF = -0.1	
Time	T1 = -0.4	$\underline{p}$ = 0.14
	T2 = -0.1	
Interaction Effect		
Session by Class		$\underline{p}$ = 0.002**
Session by Time		$\underline{p}$ = 0.65
Class by Time		$\underline{p}$ = 0.25
Session by Class by Time		$\underline{p}$ = 0.65

*Significant at the 0.05 level.

The Session by class interaction was further analyzed by using a repeated measures analysis of variance with one within - subjects factors, class (Table 10.)

TABLE 34

MEAN MICROVOLT AMPLITUDE BY TIME, SESSION AND CLASS FOR THE NEGATIVE EVOKED POTENTIAL COMPONENT RECORDED AT CHANNEL C3, N = 17

Time	Session	Class	Mean Microvolt Amplitude
T1	1	F	-4.3
T1	1	UF	-5.4
T1	2	F	-3.3
T1	2	UF	-3.8
T1	3	F	-6.6
T1	3	UF	-3.9
T1	4	F	-7.5
T1	4	UF	-2.8
T1	5	F	-5.8
T1	5	UF	-1.5
T2	1	F	0.6
T2	1	UF	-3.6
T2	2	F	-1.3
T2	2	UF	-1.1
T2	3	F	-1.7
T2	3	UF	-0.0
T2	4	F	-4.3
T2	4	UF	0.3
T2	5	F	-2.6
T1	5	UF	1.4

TABLE 35

RESULTS AND FOLLOW-UP ANALYSIS FROM A REPEATED MEASURES ANALYSIS OF VARIANCE PERFORMED ON THE MEAN AMPLITUDE OF THE NEGATIVE EVOKED POTENTIAL COMPONENT RECORDED AT CHANNEL C3, N = 17

Main Effect	Mean Microvolt Amplitude	p Value
Session	= -2.9	$p = 0.81$
Class	F = -3.7	$p = 0.08$
	UF = -2.1	
Time	T1 = -1.2	$p = 0.02$*
	T2 = -4.5	
Interaction Effect		
Session by Class		$p = 0.006$*
Session by Time		$p = 0.96$
Class by Time		$p = 0.51$
Session by Class by Time		$p = 0.88$

*Significant at the 0.05 level.

The Session by class interaction was further analyzed using a repeated measures analysis of variance with one within - subjects factors, class.

TABLE 36

MEAN MICROVOLT AMPLITUDE BY TIME, SESSION AND CLASS FOR THE PEAK NEGATIVE EVOKED POTENTIAL COMPONENT RECORDED AT CHANNEL C4, N = 17

Time	Session	Class	Mean Microvolt Amplitude
T1	1	F	-10.2
T1	1	UF	-14.3
T1	2	F	-13.4
T1	2	UF	-13.2
T1	3	F	-15.2
T1	3	UF	-11.5
T1	4	F	-15.9
T1	4	UF	-11.4
T1	5	F	-16.0
T1	5	UF	- 8.9
T2	1	F	- 7.1
T2	1	UF	- 7.6
T2	2	F	- 8.7
T2	2	UF	- 9.0
T2	3	F	-10.4
T2	3	UF	- 8.5
T2	4	F	-12.6
T2	4	UF	- 7.8
T2	5	F	-10.6
T1	5	UF	- 7.5

TABLE 37

RESULTS AND FOLLOW-UP ANALYSIS FROM A REPEATED MEASURES ANALYSIS OF VARIANCE PERFORMED ON THE MEAN AMPLITUDE OF THE NEGATIVE EVOKED POTENTIAL COMPONENT RECORDED AT CHANNEL C4, N = 17

Main Effect	Mean Microvolt Amplitude	p Value
Session	= -11.1	$p = 0.86$
Class	F = -12.0	$p = 0.051$
	UF = -10.0	
Time	T1 = -13.0	$p = 0.01$*
	T2 = - 9.0	
Interaction Effect		
Session by Class		$p = 0.056$
Session by Time		$p = 0.95$
Class by Time		$p = 0.60$
Session by Class by Time		$p = 0.60$

*Significant at the 0.05 level.

The Session by class interaction was further analyzed by using a repeated measures analysis of variance with one within - subjects factors, class.

TABLE 38

MEAN MICROVOLT AMPLITUDE BY TIME, SESSION AND CLASS FOR THE NEGATIVE EVOKED POTENTIAL COMPONENT RECORDED AT CHANNEL PZ, N = 17

Time	Session	Class	Mean Microvolt Amplitude
T1	1	F	-13.2
T1	1	UF	-15.0
T1	2	F	-13.8
T1	2	UF	-15.5
T1	3	F	-17.4
T1	3	UF	-12.0
T1	4	F	-19.0
T1	4	UF	- 9.5
T1	5	F	-12.9
T1	5	UF	-12.4
T2	1	F	- 8.6
T2	1	UF	-13.0
T2	2	F	-10.6
T2	2	UF	- 9.2
T2	3	F	-11.1
T2	3	UF	- 7.2
T2	4	F	-14.6
T2	4	UF	- 8.2
T2	5	F	-15.3
T1	5	UF	- 4.9

TABLE 39

RESULTS AND FOLLOW-UP ANALYSIS FROM A REPEATED MEASURES ANALYSIS OF VARIANCE PERFORMED ON THE MEAN AMPLITUDE OF THE NEGATIVE EVOKED POTENTIAL COMPONENT RECORDED AT CHANNEL PZ, N = 17

Main Effect	Mean Microvolt Amplitude	p Value
Session	= -12.4	p = 0.96
Class	F = -14.2	p = 0.01*
	UF = -10.7	
Time	T1 = -14.6	p = 0.02*
	T2 = -10.3	
Interaction Effect		
Session by Class		p = 0.0003*
Session by Time		p = 0.88
Class by Time		p = 0.95
Session by Class by Time		p = 0.62

*Significant at the 0.05 level.

**Significant at the 0.005 level.

The Session by class interaction was further analyzed by using a repeated measures analysis of variance with one within - subjects factors, class.

TABLE 40

MEAN MICROVOLT AMPLITUDE BY TIME, SESSION AND CLASS FOR THE SLOW WAVE EVOKED POTENTIAL COMPONENT RECORDED AT CHANNEL C3, N = 17

Time	Session	Class	Mean Microvolt Amplitude
T1	1	F	- 8.5
T1	1	UF	-10.0
T1	2	F	- 9.9
T1	2	UF	-11.2
T1	3	F	-12.0
T1	3	UF	-10.3
T1	4	F	-13.1
T1	4	UF	-10.2
T1	5	F	-10.8
T1	5	UF	-10.9
T2	1	F	- 9.0
T2	1	UF	-11.0
T2	2	F	- 9.2
T2	2	UF	- 7.7
T2	3	F	- 7.9
T2	3	UF	- 8.5
T2	4	F	-10.8
T2	4	UF	- 6.1
T2	5	F	- 6.3
T1	5	UF	- 3.3

TABLE 41

MEAN MICROVOLT AMPLITUDE BY TIME, SESSION AND CLASS FOR THE SLOW WAVE EVOKED POTENTIAL COMPONENT RECORDED AT CHANNEL C4, N = 17

Time	Session	Class	Mean Microvolt Amplitude
T1	1	F	-19.4
T1	1	UF	-21.5
T1	2	F	-19.9
T1	2	UF	-22.7
T1	3	F	-22.9
T1	3	UF	-20.6
T1	4	F	-24.0
T1	4	UF	-19.1
T1	5	F	-22.2
T1	5	UF	-18.7
T2	1	F	-16.6
T2	1	UF	-20.9
T2	2	F	-18.9
T2	2	UF	-18.9
T2	3	F	-16.8
T2	3	UF	-17.2
T2	4	F	-20.9
T2	4	UF	-16.1
T2	5	F	-16.4
T1	5	UF	-14.5

TABLE 42

MEAN MICROVOLT AMPLITUDE BY TIME, SESSION AND CLASS FOR THE SLOW WAVE EVOKED POTENTIAL COMPONENT RECORDED AT CHANNEL PZ, N = 17

Time	Session	Class	Mean Microvolt Amplitude
T1	1	F	- 9.4
T1	1	UF	-10.7
T1	2	F	- 9.4
T1	2	UF	-12.6
T1	3	F	-13.8
T1	3	UF	- 9.2
T1	4	F	-13.2
T1	4	UF	- 7.4
T1	5	F	-11.7
T1	5	UF	-10.9
T2	1	F	- 4.9
T2	1	UF	-10.0
T2	2	F	- 6.7
T2	2	UF	- 6.7
T2	3	F	- 4.2
T2	3	UF	- 7.2
T2	4	F	-10.0
T2	4	UF	- 6.2
T2	5	F	- 8.1
T1	5	UF	- 1.2

APPENDIX 6
HABITUATION OF AVERAGED EVOKED POTENTIALS IN MAN

I. Introduction

In discussing habituation of human averaged evoked potentials (EPs), attention will be drawn to sensory evoked potentials only, and in particular, visual evoked potentials occurring 10 msec or more after the stimulus and recorded from the scalp. Habituation to the absence of a strongly expected stimulus or habituation of far field evoked responses showing very early components, such as cochlear microphonics and eighth nerve responses, will not be discussed.

II. Classes of Averaged Evoked Potential Habituation

When a stimulus has been given repeatedly, the amplitudes of evoked potentials (recorded from the scalp to that stimulus tend to be reduced (Callaway, 1973). Most EP amplitude decrements have in one way or another been labeled haituation. However, the averaged evoked potential is a combination of semi-independent events such that four types of response decrements, or habituation, have been considered. These are slow habituation (occurring over the course of several minutes); fast habituation (occurring to the second of two stimuli separated by less than 10 seconds); recovery cycles (which occur with very short interstimulus intervals); and stimulus quality habituation (reflecting a change in the psychological relationships of the subject with the stimulus) (Callaway, 1973).

A. Slow Habituation. Slow haituation is generalized to all components of the evoked response from 100 to 300 msec; is best seen is visual EPs; is indicated by a 2-10% reduction in maximum amplitude; and, in part, may be the result of peripheral receptor adjustment; and, finally, is influenced by stimulus quality habituation (Callaway, 1973).

When approximately 50 stimuli is generally larger than the EP for the second half. This fundamental phenomenon of slow habituation has been repeatedly demonstrated in a number of earlier studies (Bogacz et al., 1960; Haider et al., 1964; Perry and Copenhaver, 1965). Decrements have been reported to occur in components from 100 to 300 msec after stimulation. Just why some investigations find decrements in one component and not in another remains unclear. One possibility is that the variability of components from subject to subject and from situation to situation resulted in investigations noting decrements in only those components that were particularly prominent in their study.

Slow EP habituation appears to be the result of a combination of factors such as peripheral adjustments, looking away from a visual stimulus, and pupil constriction which reduces light entering the eye. Central adjustments also occur over time. The subject may lose interest in the stimulus, become fatigued and less aroused. Thus, fatigue and boredom, paralleled by changes in background EEG, and a variety of peripheral adjustments may result in a reduction of the impact that a stimulus has on the central nervous system.

Evidence for the role of pupil size in the visual averaged evoked potential (EP) decrement has been presented by Bergamini and Bergamasco (1967). Flashing a light once each second, they demonstrated a reduction in EP amplitude over the course of about 10 minutes. Dilating and fixing the pupil with a mydriatic drug, however, prevented any response decrement from occurring even after 30 minutes of stimulation. In interpreting these results, however, it is important to remember that the dilated pupil admits more light, and this increased stimulus intensity may have prevented habituation (Callaway, 1973).

Naatanen (1967) found that an artificial pupil prevented habituation to regular visual stimuli (2-second ISI).

Although the two studies above indicate pupil size does play a role in visual EP slow habituation, this is probably not the entire story. Perry and Copenhaver (1965) reported that myosis produced by either 10% neosynephrine or 0.05% enclopentolate did not influence habituation to regular 3.8 per second flashes, nor did an artificial pupil. They reported that, independent of pupillary changes, stimuli in the center of the visual field produce slower habituation than more peripheral stimuli, presumably because stimuli are more effective (i.e., stronger) at the fovea.

The role of change in attitude (i.e., interest, attention, uncertainty, etc.) to the stimulus properly comes under the heading of stimulus quality habituation, which will be discussed in Section II,D. However, some pertinent experiments on this phenomenon have used the slow habituation type of design. For example, Haider et al (1964) had subjects watching 3-per-second light flashes and attempting to detect occasional slightly dimmer flashes that occurred about once every set of 10 bright flashes. Averaged evoked potentials were obtained from sets of 100 bright flashes over the course of about 16 sets. They reported a relatively monotonic decrease in performance over time and a relatively monotonic decrease in the amplitude of a negative component approximately 160 msec after the stimulus. Super-imposed on this montonic trend were parallel fluctuations in the amplitude of the averaged evoked potential and fluctuation in the accuracy of the subject's performance. Even in early trials, when subjects made errors, their EPs were lower than when they were successful in the detection task. This indicates that the drop in amplitude correlated with poor performance was not entirely a function of habituation over time. This finding, however, becomes somewhat less surprising when one remembers that blinking, looking away, etc., will cause the subject to miss an occasional dim flash and will also reduce the EP amplitude. This may also account for the increase of latency that accompanied the decrease in amplitude (Callaway, 1973). In general, increasing stimulus strength increases amplitude and reduces latency, which increases attention to the stimuli, increases amplitude and increases latency, at least in the latter (latency 100 msec) EP components. Different results, however, were obtained with an auditory version of the above study. Wilkinson et al. (1966) reported increases in auditory averaged evoked potentials with reduced vigilance.

In summary, repeated stimulus presentations are accompanied by changes in the averaged evoked potential. Typically there is a response decrement (slow habituation), although a concomitant reduction in arousal may be accompanied by increased amplitude of some of the later components (Callaway, 1973).

B. Fast Habituation. Fast habituation is a reduction in the EP amplitude that occurs when less than 10 seconds elapses between presentations of stimuli; is generalized to most components from 100 to 300 msec; shows response decrements to 80% or more of maximum amplitude depending upon interstimulus interval (Nelson and Iassman, 1968); is probably independent of peripheral adjustments; and may include a recovery cycle component (Callaway, 1973).

Allison (1962) studied what he referred to as recovery cycles in the human somatosensory EP. He noted that components 20 msec after stimulus offset recovered in 200 msec, components 40-80 msec poststimulus recovered in 1 second, but that late components took several seconds to recover. It is these later components that will be discussed.

If stimuli are presented in a regular series, the amplitude of the EP is a monotonic increase function of the interval between stimuli. Furthermore, if the stimuli are aperiodic, then this response decrement is not too prominent. Thus, it might be correct to refer to fast habituation as stimulus timing habituation (Callaway, 1973).

Fast habituation in man is easy to demonstrate by presenting trains of two or more stimuli separated by 2 seconds and by allowing a rest of 10 seconds or more between the trains. With such a procedure, average responses to stimuli occurring second or later in the train may have as little as half the amplitude of responses to stimuli occurring first in the train (Callaway, 1973). In visual evoked response with some subjects, a somewhat different phenomenon may occur. Response to the first stimulus may be modest; that to the second may be largest; and that to the third stimulus the smallest. This was interpreted by Callaway (1973) as indicating that the subject's gaze wandered from the stimulus source; the first stimulus of the train recalls the subject to the task; the second stimulus then produces the largest evoked response, with the third stimulus the smallest EP, as the full effect of fast habituation finally occurs.

In summary, fast habituation (i.e., response decrement) occurs with regular interstimulus intervals of less than 10 seconds. This response decrement is approximated by a logarithmic function of the center stimulus interval and is dependent upon the subject's knowledge of that interval.

C. Recovery Cycles. The concept of the recovery cycle arises out of studies on single nerve cells when there is a refractory period resulting from membrance depolarization following a spike discharge. Following activation aggregates of cells show similar periods of unresponsiveness; however, in such cases the period of unresponsiveness usually reflects an active inhibitory process rather than the temporary exhaustion typical of a physiochemical system (Callaway, 1973).

However, as recovery cycle data deal with interstimulus intervals of 100 msec or less, and very early EP components (N15-P31), the concept is presented for the sake of completeness only. For a more comprehensive understanding of the recovery cycle, see Allison (1962), Shagass and Schwartz (1963), Shagass et al. (1969), and Shagass and Straumnair (1969).

D. Stimulus Quality Habituation. Stimulus quality habituation depends on the subject's attitude toward the stimulus; primarily affects EP components with latencies of 300 msec or more; may augment or diminish EP amplitude; is not entirely dependent on peripheral receptor adjustment; and includes very low frequency components (Callaway, 1973).

Two related EP components which respond to changes in the way the subject relates to the stimulus are the contingent negative variation (CNV) and the P300 wave.

The CNV is increased by increasing interest in the imperative stimulus, by increasing the physical effort required for responding to the imperative stimulus, and by reducing the subject's uncertainty about the time of arrival of the imperative stimulus. Note that a reduced CNV is thus not likely to contribute to fast habituation, for in fast habituation uncertainty about timing increases EP amplitude. The CNV, however, plays a role in stimulus quality habituation since the CNV will decrease as the subject loses interest in the stimulus (Callaway, 1973).

A second phenomenon is the P300 wave. Ritter et al. (1968) have considered this component to reflect an orienting response. In general, the more significant and unexpected and surprising a stimulus is, the greater will be the P300 response to it.

Certainly a variety of evoked potential components have been reported as reflecting a number psychological processes. These psychological processes, such as learning and information processing, are currently being investigated in literature. For the time being, however, the most parsimonious understanding of those evoked potential components reported to reflect psychological phenomena is that with repeated stimulus presentation they tend to decrease (i.e., exhibit habituation) (Callaway, 1973).

There is some suggestion that is stimulus quality habituation and peripheral sensory reception adjustments were controlled, slow habituation may not be present at all (Callaway, 1973). That is, it is known that with repeated presentation of visual stimulus pupillary constriction occurs, along with wandering visual fixation and changing interest in the stimulus. Were these to be controlled, Callaway (1973) suggests that perhaps traditional slow habituation in EP components would not occur. He points out that while this remains an empirical question, evoked potential response decrement appears to be attributable to a number of interacting factors.

III. Summary of Findings

With repetitive stimulus presentation a decrement in EP components is typically reported. Slowly, over 20 or more trials, the EP drops in amplitude. Some of this response decrement is the result of peripheral adjustments (e.g., pupillary constriction and a change in gaze), and some is the result of a change in interest to the stimulus.

In most evoked potential studies, there are three primary types of habituation operating: a slow habituation reflecting, among other things, peripheral sensory adjustments; a fast habituation logarithmically related to interstimulus interval and dependent upon the subject's knowledge of that interval; and finally, a decrement in the EP reflecting the subject's interest in the stimulus, stimulus quality habituation. When evoked potentials are recorded with less than 10 seconds between stimuli, and without controlling for changes in gaze and interstimulus iterval, any EP emplitude measurement is probably influenced by all three types of habituation (Callaway, 1973).

IV. Discussion

In the present study factors which contribute to slow and fast habituation were controlled for. Peripheral receptor adjustment such as blinking and eye movement during stimulus presentation, were monitored and excluded from data analysis. Pupillary changes were not recorded in the present study.

In the habituation literature pupil response has tended to be interpreted as reflecting level of arousal. However, more recent evidence in the area of information processing suggests that the pupillary response is correlated with cognitive processes, such as learning and memory (see Kahneman, 1973). Future studies using an eye movement and pupil response instruments would provide even greater specificity in this area of research. For the present study, however, it was felt that because of the controls used, slow habituation response decrement attributable to artifact (looking away, blinking, etc.) was significantly reduced.

Response decrement due to fast habituation was also controlled for in the present study. The interstimulus interval was random and not regular; furthermore, a different and random order of stimulus presentation was used for each of the 5 trials. The assumption that fast habituation was controlled for is supported by the finding of Laurian and Gaillard (1976). In this study visual evoked responses to light flashes presented at fixed (1-sec) and random inter-stimulus intervals (1.2-4 sec) were collected. A gradual decrease of amplitude in N1 and P2 components was observed with a fixed interstimulus interval. No decrement was observed with random interstimulus intervals.

Response decrement in components of the visual evoked responses collected in the present study was, therefore, interpreted as primarily reflecting what Callaway (1973) has called stimulus quality habituation. Recall that this type of habituation is attributable more the subject's level of arousal, stimulus novelty, or psychological processes, such as attention and learning, and less attributable to peripheral factors. In the present study, along with peripheral factors already discussed, novelty or uncertainty of a stimulus was also controlled for. In sessions 2-5 the probability for each of the two classes of slides, familiar and unfamiliar, was .50. In session 1 all slides were unfamiliar. Therefore, a differential response decrement between the two classes of slides could be assumed to reflect differences in either level of arousal and/or psychological processes. And, given that a subject's arousal level is a pervasive and not a selective phenomenon, it is not unreasonable to assume that level of arousal would uniformly affect components of the evoked response, and not in a selective of a differential way. For example, in the comparison of EP components between two classes of stimuli, if component 1 of Class A is not different from component 1 of Class B, while component 2 does differ by class, an explanation other than arousal would be needed to account for such differential results.

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BIOGRAPHICAL SKETCH

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Nathan W. Perry, Jr., Chairman
Professor of Clinical Psychology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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